DOCUMENT RESUME

ED 097 817 HE 005 971

TITLE	Perspectives and Plans for Graduate Studies. 11. Engineering 1974. C. Metallurgical and Materials Engineering. Report No. 74-15.
INSTITUTION	Ontario Council on Graduate Studies, Toronto. Advisory Committee on Academic Planning.
PUB DATE	74
NOTE	226p.
AVAILABLE FROM	Council of Ontario Universities, 130 St. George Street, Suite 8039, Toronto, Ontario M5S 2T4 ($5.00)
EDRS PRICE	MF-$0.75 HC-$11.40 PLUS POSTAGE
DESCRIPTORS	Doctoral Degrees; Doctoral Programs; Educational Quality; *Engineering Education; Enrollment Trends; *Foreign Countries; Graduate Students; *Graduate Study; *Higher Education; Labor Market; *Metallurgy; Program Evaluation
IDENTIFIERS	*Canada; Ontario

ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning in coordination with the Committee of Ontario Deans of Engineering has conducted a planning assessment for doctoral work in metallurgical and materials engineering. A consultants' study of metallurgical and materials engineering is presented, encompassing interpretation of metallurgical engineering; the supply of and the demand for manpower; the quality of the educational experience; assessment of the programs at McMaster University, University of Toronto, Queen's University, University of Waterloo, University of Western Ontario, University of Windsor; and interuniversity cooperation in Province of Ontario. Consultants' recommendations and recommendations of the council are presented in addition to general recommendations concerning other discipline areas. (MJM)

ED 097817

Council of Ontario Universities
Conseil des Universités de l'Ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

11. ENGINEERING 1974*

C. METALLURGICAL AND MATERIALS ENGINEERING

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*The status of this report is given in Item 2 of the statement of principles, on page 1.

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This report deals with a planning study of doctoral work in engineering, which was conducted in several portions corresponding to the various disciplines within engineering. The report is in six volumes. Volume A deals with chemical engineering, B with electrical engineering, C with metallurgical and materials engineering, D with mechanical engineering, E with industrial engineering, and F with civil engineering. Each volume contains the COU and ACAP reports for engineering as a whole together with the consultants' report and other material appropriate to one of the disciplines. The COU report will be in three parts: Part I dealing with the recommendations approved in June 1974 and dealing with most of the fields, Parts II and III to appear later dealing with mechanical and industrial engineering, and with civil engineering respectively. This volume, printed in the summer of 1974, contains only Part I.

FOREWORD

As a consequence of a study of engineering education in Ontario (described in more detail in the subsequent ACAP report) the Council of Ontario Universities called for a planning assessment of PhD programmes in engineering to be carried out by ACAP in cooperation with CODE.

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

The disciplinary planning process involves a discipline group composed of one representative from each university with an interest in graduate work in the planning area. In the case of engineering, CODE was also involved in a way described in the ACAP report. The discipline group assists in defining the precise academic boundaries of each study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the disicpline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasis of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part I

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering, has conducted a planning assessment for doctoral work in engineering. This arose from the need to re-examine the recommendations concerning PhD work which appeared in Ring of Iron. The background to the study, the procedures followed and the planning techniques used are described in the ACAP report and are not repeated here. The resultant report from ACAP is attached together with the consultants' reports, the comments by the discipline groups, the comments of the individual universities, and the comments of CODE. It is important for the reader to read the attachments in order to understand the recommendations in this Report from COU. COU will issue subsequent parts to this report dealing with mechanical, industrial and civil engineering.

The Council received the ACAP report and supporting documentation on April 11, 1974. The content of the ACAP document was debated on April 11, on May 3, and on June 7, 1974. As a result of these discussions this Report and Recommendations was prepared and approved by the Council on June 7, 1974. The report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments makes this difficult. However, by the summer of 1974 there will have been assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas. On the information and recommendations then available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly-based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plan.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning engineering doctoral work

1. Ontario is unlikely to over-produce engineering PhD's in the next five years. However, the student body contains too large a proportion of non-Canadians. Qualified Canadians should be encouraged to seek the engineering PhD.

2. Doctoral students should be selected on the basis of high academic standing and research potential.

3. "Inbreeding" is a problem, with many students obtaining three degrees from one university.

4. Faculty members, whether or not engaged with doctoral students, should have the facilities and opportunities to engage in research and in work with industry.

5. The scope for inter-university and university-industry cooperation is considerable and should be exploited.

6. The quality and state of development of the Ontario doctoral programmes are variable. Some are very good and have gained international recognition.

7. Some universities are organizing (or reorganizing) doctoral study on a division of specialization other than that provided by the "traditional" engineering departments. In two of the smaller faculties this is a central factor in the planning, but increasing cross-departmental activity is also in evidence elsewhere.

Actions by COU

1. COU has abandoned a planning number of 450 doctoral students and advises the universities to plan on the assumption that the doctoral enrolment will remain roughly constant for the next five years. Although there is a need for engineers with doctorates in Ontario, graduate student enrolment will level off due to a lack of top quality students. Canadians must be attracted in increasing numbers in order to maintain enrolment at the present level.

2. COU requests that CODE report annually to COU on enrolment and employment opportunities.

3. COU requests that ACAP arrange for each engineering discipline group:
   (1) to monitor annually the admissions experience of each programme (post _facto_) and report on the quality of the admitted students (to ACAP for transmission to COU);

   (2) to report annually to ACAP on the universities previously attended by the newly admitted graduate students of each department.

4. COU requests CODE, after consultation with the discipline groups, to develop proposals for collective methods of making information on graduate work in all Ontario universities readily available to the engineering students, and to inform ACAP of the action taken.

5. COU requests OCGS to examine existing university guidelines on part-time doctoral work and its supervision.

6. COU request that ACAP arrange for an annual report to OCGS from each university on the time taken for each graduating student to complete his doctoral studies.

7. COU requests ACAP to examine the available documentation on civil engineering, to reach its own judgements on the basis for a report, after soliciting assistance from the discipline group and the universities, and to prepare its report to COU containing recommendations for the future of civil engineering doctoral work. This should be submitted by December 31, 1974.

8. COU requests that ACAP arrange for the metallurgical and materials engineering discipline group to present a report to ACAP on university actions taken to correct identified weakness in certain fields of study.

Recommendations

It is recommended that:

1. Universities, CODE and discipline groups take steps to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

2. The universities attempt to maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

3. The universities, the provincial government, and granting agencies examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined.

4. All doctoral thesis examining committees have an examiner external to the university.

5. At present, there not be any specific engineering doctoral part-time programmes but rather that part-time or non-resident doctoral work be done by individual arrangement. Experimentation in methods of carrying on part-time work is to be encouraged and might lead in future to the creation of specific part-time programmes. It is also recommended that the research topic of any student accepted on a part-time basis be in a field in which the professors in the department have expertise.

University Recommendations

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

It is recommended that:

6. The University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. If a favourable appraisal is not obtained by the end of October, 1976, admission of new students should then be suspended.

7. The University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained.

8. The involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the university begin doctoral work in agricultural engineering at a time in accordance with the university's plans, subject to normal appraisal procedures.

Chemical Engineering

This section deals with doctoral work in chemical engineering at McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

9. The departments consider grouping their research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

10. McMaster University continue its doctoral work in chemical engineering according to its plans.

11. The University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

12. Queen's University re-evaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the university considers appropriate. If a favourable appraisal has not been received by October, 1976, enrolment of new students then be suspended.

13. The University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to the desirable mobility of its bachelor's graduates for graduate work elsewhere and to the desirability of grouping of research areas. The University of Toronto is requested to report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

14. The University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

The consultants' report is unfortunately inadequate for planning purposes.

It is recommended that:

15. The embargo on the funding of any new programmes in civil engineering continue until COU has accepted a report from ACAP dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted by ACAP by December 31, 1974.

Electrical Engineering

This section deals with doctoral work in electrical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

16. The discipline group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and

make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

17. Carleton University continue its doctoral work in electrical engineering according to its plans.

18. McMaster University continue its doctoral work in electrical engineering according to its plans.

19. The University of Ottawa plan the reorganization of its doctoral programme in electrical engineering and put forward the programme for appraisal. If a favourable appraisal has not been obtained by the end of the fall term 1976, admission of new students should cease. In the meantime, enrolment of new students should be restricted to the digital communications systems and large-scale systems fields.

20. Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields should be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

21. The University of Toronto continue its doctoral work in electrical engineering according to its plans.

22. The University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Metallurgical and Materials Engineering

This section deals with doctoral work in metallurgical and materials engineering at McMaster, Queen's, Toronto and Waterloo.

It is recommended that:

23. The universities take steps to increase the activity in the ceramics, glasses, and polymer fields of study in the province.

24. McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and make a report to COU through ACAP in the fall of 1975 on the following suggestions for improvement:

    a) recruitment of students with physics and chemistry backgrounds
    b) strengthening of the extractive metallurgy faculty
    c) collaboration with the University of Toronto

25. Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors from other departments. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish

to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

26. The University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto consider broadening the programmes and it is requested that the university report to COU through ACAP by September, 1975, on any progress made in this direction.

27. The University of Waterloo continue its doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

It is recommended that:

28. Queen's University continue its doctoral work in accordance with its plans.

General

It is recommended that:

29. In view of the acceptance of these recommendations by the Council of Ontario Universities and the completion of Part I of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on doctoral work in Engineering (except for Mechanical, Industrial and Civil Engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo), in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study has been conducted.

Notes concerning the recommendations

Re: Recommendations 1, 2, and 3

The background to these important recommendations appears on pages 13 and 14 of the ACAP Report.

Re: Recommendation 7

Presumably the programmes submitted for appraisal will be the three divisional programmes which are replacing the departmental programmes.

Re: Recommendation 16

Other engineering discipline groups may also find this a valuable suggestion.

Re: Recommendation 19

This differs from the recommendation in the ACAP Report because the University subsequently decided to carry out a re-assessment of the future direction of the department.

Re: Recommendation 25

Queen's has reported to COU its intention to enlarge its programme in extractive metallurgy.

June 7, 1974.

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ADVISORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES
ON
ENGINEERING DOCTORAL PLANNING ASSESSMENTS

JUNE 7, 1974

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For each planning assessment (Chemical, Civil, Electrical, Mechanical, Metallurgical, and Industrial) there are appended:

Appendix A - Consultants' Report

Appendix B - Discipline Group Response

Appendix C - University Comments

Appendix D - Procedure of Planning Study and Terms of Reference

Appendix E - Discipline Group Membership

Appendix F - Roles of ACAP and of Discipline Groups

Appendix G - Curricula Vitarum of the Consultants

Appendix H - CODE Response

I. RECOMMENDATIONS

General Recommendations

C1

It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU or enrolment and employment opportunities.

C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

C6

It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

C7

It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

University Recommendations

C10

It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained by that date.

C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the ~~University~~'s plans, subject to normal appraisal procedures.

Chemical Engineering

C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

C17

It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

C18

It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

C19

It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

Electrical Engineering

C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

C24

It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

C25

It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

C26

It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Mechanical Engineering

C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Metallurgical and Materials Engineering

C31

It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these recommendations.

C32

It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:

a. recruitment of students with physics and chemistry backgrounds

b. strengthening of the extractive metallurgy faculty

c. collaboration with Toronto.

C33

It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

C34

It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975, on any progress made in this direction.

C35

It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

C36

It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

Industrial Engineering and Systems Design

C37

It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

C38

It is recommended that the University of Waterloo continue its doctoral programme in systems design.

II. BACKGROUND AND PROCEDURE

In June, 1968, the Committee of Presidents of the Universities of Ontario, after a meeting with the chairman of the Committee on University Affairs, decided that a comprehensive review of engineering education in Ontario should be undertaken. The Committee of Ontario Deans of Engineering (CODE) was requested to draw up plans for such a study, and this proposal was approved by the Committee of Presidents on November 15, 1968. The objective was to create a master plan which could be used as a guide for rational growth of engineering education during the 1970's. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, opportunity for innovation, and maximum freedom of choice for students.

This study culminated in the report Ring of Iron prepared by a commission chaired by Philip Lapp.

The report was received by the Committee of Presidents in January, 1971. A process of review of the report's recommendations was established, CODE prepared a brief based on statements of views submitted by each university concerned and by each Faculty of Engineering. Briefs were prepared also by the Ontario Council on Graduate Studies (OCGS) and the Association of Professional Engineers of Ontario. On October 5, 1971, the Council of Ontario Universities (COU) considered Ring of Iron and the briefs and prepared a statement of recommendations to the universities and to CUA.

COU accepted a number of the Lapp recommendations without change, others with amendments and rejected some. Broadly speaking, the recommendations to do with undergraduate matters were accepted or modified slightly. The graduate area of the report was more controversial, but here also some recommendations were accepted. The most significant of the recommendations concerning graduate study, as approved by COU, are:

> "The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level."
>
> "Both universities and industries should recognize joint appointments as part of the career structure of their senior staff; these appointments should be increased as far as possible..... By this we understand a system of part-time appointments."
>
> "Over the next two years the estimated graduate enrolment of 2,000 full-time equivalent students for 1970-71 be reduced by 17%, after which graduate enrolment should be limited to a number equal to the previous year's bachelor graduations. The enrolment figure applies to the engineering departments as identified in Ring of Iron".

> "The recommendation that the number of PhD students enrolled be reduced to 450 per year is fully supported by all groups including COU. However, COU, along with CODE and OCGS, recommends that the figure of 450 be the target for 1974-75, rather than for 1973-74, for reasons related to avoiding large fluctuations in enrolment as explained in the OCGS critique."
>
> "The Lapp report recommends specific numbers of PhD enrollees for each of the universities including discontinuance of the PhD enrolment in certain universities. COU feels that the reasons for the numbers chosen or for the elimination of certain doctorate programmes are not fully documented in the Lapp report. COU also agrees with CODE and OCGS that attention must be given to the numbers of doctorate enrollees by discipline as well as by university. For these reasons COU recommends that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programs to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

On receipt of this instruction from COU, ACAP and CODE established a liasion committee (Ayers, Dillon, Ham, Johnson, Shemilt, McIntosh, Preston) which drafted procedures for the assessments. It may be noted that the committee considered a model in which the assessments were based, not on the five traditional departments found in engineering faculties, but rather on interdepartmental areas of research; the practical difficulties of conducting the assessments led the committee to recommend the five-fold subdivision actually used.

The procedure developed in this way was approved by ACAP on March 17, 1972, and by COU on April 7. The procedure (except for minor data amendments) is that in Appendix D to this report. In writing to indicate its approval CODE expressed their understanding that two objectives would be met:

> "1. To provide a rational basis for doctoral work in engineering and for confirming or modifying the limitation on enrolment suggested by Lapp.
>
> 2. To conduct a really effective assessment of the quality of our current doctoral programmes."

CODE went on to emphasize the need of adequate resources to obtain the best consultants.

In order to begin the planning assessments, the ACAP/CODE liasion committee called a meeting of members of the five Discipline Groups (Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering). This meeting on April 12, 1972, indicated a good deal of faculty resistance to the conduct of the planning assessments and uneasiness about some perceptions of some aspects of the approved procedures. This resulted in a delay in mounting the assessment. CODE suggested a Coordinating Task Force, consisting of two members of CODE, the chairman of each Discipline Group, and a member of ACAP could review the procedures. ACAP advised COU to agree to this request and the COU executive did so on June 9, 1972. This Task Force held meetings on June 29, July 27, September 1, September 25, November 29, 1972 and March 19, 1973. It suggested two slight additions to the procedures as approved earlier by COU. These were approved by COU on September 25, 1972. The Task Force also produced a document clarifying some aspects of the procedure in detail, and a statement of some educational philosophies concerning doctoral study. These documents are referred to in the terms of reference of the consultants. The Task Force also advised ACAP (and so did universities) on how to take into account for planning purposes those doctoral programmes in Faculties of Engineering which did not fall obviously into the fields covered by one of the five consulting teams. It was eventually decided that:

a) both the metallurgy and the mechanical engineering consultants would be asked to consider the metallurgical work within the Department of Mechanical Engineering at Waterloo

b) no advice from external consultants would be sought on the doctoral programme in mining engineering at Queen's

c) a small-scale "planning assessment" involving two consultants would be carried out in industrial engineering and systems design

d) in view of the fact that all current doctoral students at Guelph are in hydrology and that the field of agricultural engineering is also proposed, the civil engineering consultants would be asked to consider the Guelph doctoral work, with the understanding that if they so wished ACAP would facilitate a consultation for them with someone in a department of agricultural engineering

e) the mechanical engineering consultants be asked to consider the doctoral work at the University of Toronto Institute of Aerospace Studies and in aeronautical engineering at Carleton, with the request that they consult also with another of the ACAP consultants (on the Electrical Engineering team) who had expertise in some of the UTIAS work outside mechanical engineering and also with an aerospace specialist

f) advice on the future plans of the Department of Management Science at Waterloo would be sought from the consultants in the planning assessment in Administration, Business and Management Science, with a comment also provided by the consultants on industrial engineering.

g) no special arrangements were needed in connection with biomedical engineering at Toronto since the corresponding institute has no graduate programme of its own, and the future doctoral plans are covered in the statements from each of the associated departments.

Item f will be dealt with in a later report. The remainder are covered in this report. The mechanical engineering consultants informed ACAP that they did not require the assistance suggested in item e.

In October, 1972, CODE proposed that a study be carried out, under the aegis of the newly established Canadian Engineering Manpower Council, and with financial support from a number of agencies, in order to make recommendations about "supply and demand" for engineering doctorates. This would be expected to be of great value to the planning assessments. ACAP agreed to this suggestion, provided funds towards the costs, and incorporated reference to the study into the instructions for the consultants. In the event, the study proved rather disappointing; it is discussed later in this report.

As a result of suggestions from the Discipline Groups and after receiving comments from the Coordinating Task Force and from CODE, ACAP agreed on consultants at its meetings of September 7-8, October 13 and December 18, 1972. The consultants who finally acted were:

Chemical Engineering:	Dean P. Grenier of Université Laval, Dean W. R. Marshall of the University of Wisconsin, Professor L. Yaffe of McGill University
Civil Engineering:	Professor W.W . Eckenfelder of Vanderbilt University Mr. B. V. Martin of Alan M. Voorhees and Associates Ltd., Professor G. G. Meyerhof of Nova Scotia Technical College, Dr. J. L. Boulet of Hydro-Quebec.
Electrical Engineering:	Professor A. D. Moore of the University of British Columbia, Professor M. E. Van Valkenberg of Princeton University, Dr. M. P. Bachynski of RCA Research Laboratories

Mechanical Engineering: Professor H.W. Emmons of Harvard University, Dean G. Ford of the University of Alberta, Dr. R. D. Hiscocks of the National Research Council of Canada, Professor S.G. Mason of McGill University

Metallurgical Engineering: Professor J.J. Jonas of McGill University, Professor T.B. King of the Massachusetts Institute of Technology, Professor W.S. Owen of Northwestern University and M.I.T., Dr. W.B. Lewis of Atomic Energy of Canada Ltd.

Brief curricula vitarum appear in Appendix G. In each case, the last named person played the role of a senior Canadian from outside the discipline.

The consultants held their first meetings at various dates in April and May, 1973 and in each case met with the appropriate Discipline Group, arranged the schedule of visits, discussed their character and had general discussion with the Discipline Group about the task before them. The visits took place in the two or three months following these meetings.

The consultant teams each submitted a draft report in September, which was the subject of oral discussion with the Discipline Group at a meeting within a few days of the receipt of the draft. Each consultant team then submitted its report. These reports were sent for comments to the universities, to the Discipline Groups and to CODE, each of which sent comments to ACAP at various dates in November, December and January.

A subcommittee of ACAP began consideration of the report to COU, before all the comments were in hand and continued its work through March, 1974, reporting regularly to ACAP and receiving instructions. Early in its meetings the committee identified some points on which further information and reactions were required. In particular, the need for fuller advice from the consultants was felt in the cases of civil and mechanical engineering. Such further advice was sought, with results discussed in the relevant sections of this report. ACAP also thought some further information would be helpful in connection with three of the universities and arranged meetings with officials of these universities and members of ACAP.

This report is based on the consultants' reports, the data collected for the study, the universities' comments and supplementary material from some of them, the Discipline Groups' responses, and the other documentation referred to in the procedures and terms of reference. The report sets out recommendations for COU on doctoral work in engineering in Ontario for the next few years.

As is required, ACAP presents this report directly to COU. It has also been transmitted for information to OCGS, CODE, and the Discipline Groups.

III. GENERAL RECOMMENDATIONS

This section of the ACAP report contains recommendations that are of general concern to all of engineering. Some of these recommendations have been mentioned consistently in all the reports while others, although found in only one report, are applicable to all doctoral programmes.

Enrolment and Manpower Forecasts

In the summer of 1973, the Canadian Engineering Manpower Council released its report entitled Supply and Demand for Engineering Doctorates in Canada. This report was partly financed by ACAP and was given to all the consultant teams prior to their writing of their reports. It generally states that the supply of engineers in the next five years will exceed the demand.

A summary of the comments made by the engineering consultants concerning this report shows that they all independently disagree with the projections made in the CEMC report. They believe there has been no overproduction of PhDs to date and, in fact, there appears to be a shortage of metallurgical PhDs. Each team believes that the need for engineers will not decline, as predicted by CEMC but that the overall demand will continue and in actual fact, all but the civil engineering consultants believe it will increase.

ACAP had originally intended to publish a critique of the CEMC report. However, CODE in its repsonse to the engineering reports, Appendix H, has included a statement on this report covering all the points ACAP wished to make. ACAP's critique will not be reproduced, but we feel that the CEMC report is not an adequate basis for manpower planning in engineering. Since all the consultants agree that supply will not exceed demand but perhaps rather the reverse, the question of supply of qualified students must be studied. The main problem will be attracting Canadians into engineering graduate work. In 1972-73, of the 518 F.T. engineering PhDs, 28.6% were Canadian, 53.3% were landed immigrants and the remaining 18.1% were on student visas.

Changes in the immigration regulations make it harder to become a landed immigrant. Since one can no longer apply for landed immigrant status while in Canada, those that come on student visas will presumably return to their homelands. Coupled with this is another new regulation that a teaching assistantship is no longer classified as a job, thus making it harder to obtain landed immigrant status. Consequently, ACAP feels that the percentage of landed immigrants in graduate work will drop while the number of students visas will increase. Financial support for people on student visas is scarce. There are very few scholarships or bursaries open to them but in engineering they may be supported from contract funds. In any case, there will be funds for only a few. Although Canada has a role to play in providing advanced technical education for the underpriviledged countries of the world, this should be kept to a reasonable level and should not exceed 30% of engineering doctoral enrolments.

CODE, on page H-9 of its response, states that "unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline". There are suggestions that student stipends be increased. We remain unconvinced that stipends need be any higher in engineering than in any other field, but there is one exception and this is that people with substantial professional experience returning to graduate study should be supported at a higher level.

ACAP is inclined to agree with the University of Waterloo's comment, page G-29 in its response to the chemical engineering report, that the best way of attracting Canadian students is a "change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry". Increased dialogue with industry as well as up-to-date information on jobs available would make the employment picture brighter and more alluring to prospective Canadian graduate students especially if the number of industrial scholarships were increased and more interaction were seen to be taking place between industry and university.

This dialogue with industry is needed to ensure that more Canadians continue in graduate work. If industry indeed has a place for the master's or doctorate in engineering, more must be done to encourage good students to stay in university instead of taking a job after the bachelor's degree. Industry in its hiring policies can encourage this.

The chemical engineering consultants recommend that the universities should endeavour to develop entrepreneurship in students. They feel "this is a quality so badly needed at present in Canada".

It does not seem as though Ontario will overproduce engineering PhDs in the next five years. The question is rather whether there will be enough qualified students. In view of this possible shortage, the following recommendations are made by ACAP.

Recommendation C1

> It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

Recommendation C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

Recommendation C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

Recommendation C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

Admissions

ACAP does not support the view held by the electrical engineering consultants, namely that admitted doctoral candidates should have first class standing and proven research ability. Many students who graduate with high second class honours have become excellent research engineers. The usual minimum standard of the better departments is a high B and all the consultants agree that high standards of admissions prevail generally.

Recommendation C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

CODE agrees with ACAP on the annual post facto analysis of admission practices (page H-3). The chemical engineering consultants have suggested "that should it be found that students have been accepted who, in the opinion of the committee, do not fulfill the minimum requirements, the committee advise COU that a recommendation be made to the requisite authority suggesting no BIU be awarded for that student". ACAP does not feel this to be necessary at the present since regular reporting by the Discipline Group should exert considerable pressure if an institution repeatedly admits students of a low standard.

Undergraduate-Graduate Relationship

Some consultants assert that each department should provide all levels of study: bachelor's, master's and doctoral. Some go so far as to say that a doctoral programme in each department is essential. CODE, on the other hand, feels that what is important for a good undergraduate programme is research and professional activity by the faculty, and that this can be carried forward without graduate students, although at present the research activity is most easily carried on through graduate programmes (page H-3). ACAP agrees with the position stated by CODE and indeed applies it to all subjects, not only engineering, but with the comment that in many fields it is not difficult for a professor to be active in research without having graduate students. We would point out that the other position would imply that no department should exist unless it can operate an effective doctoral programme, a view which we find impossible to accept. The absence of sufficient research and professional activity by professors would raise questions about the quality of a department and hence of its undergraduate offerings, whether or not it offered doctoral work.

Thesis Quality

Recommendation C6

> It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

Since some of the consultants have made reference to the make-up of examining committees ACAP would wish to endorse this practice of including an external examiner.

Critical Size

We agree with CODE that there must be sufficient range of interaction for the student and that the judgement as to the presence of this interaction must include consideration of the involvement of persons outside the student's department and should include post-doctoral fellows and research associates as well as students. Although these planning assessments were vertical, as CODE suggests, each department was asked to state the extent of this interaction in its university. We agree that there is no a priori reason why a small school cannot provide as satisfactory an environment as can a large school. The question is not one of principle, but one of fact: does university A in fact provide the requisite environment for interaction for the average student in its department X?

Most of the consultants considered this question carefully and made specific comments but others provide no evidence that they examined the matter in any of the universities. While most agree that successful programmes can exist in small as well as large departments, the consultants still expect a wide range of courses to be offered. This in turn requires a certain number of students to make the courses economically feasible and academically stimulating.

Mobility of Students

The chemical engineering consultants are concerned about the lack of mobility of engineering students. They do not consider it a good educational experience to study for all three degrees, the bachelor's, the master's and the doctorate, at the same university. Such a programme leads to inbreeding and sameness and precludes any chance for the student to come in contact with different faculty, students, milieu and methods.

One sometimes hears a professor accept this in theory, but then say that in practice the student must not be prevented from going to the university of his choice. That view appears to us to be correct, provided the student's choice is made on sound academic grounds, based on good information of the opportunities that are available to him, and taking account, of course, of the undesirable aspects of remaining in one university.

Recommendation C7

> It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

Part-time Programmes

In 1972-73, 18% of the doctoral students studying engineering were doing so on a part-time basis. 65% of these students were Canadians and another 32.5% were landed immigrants. It would appear that these part-time programmes are being used by the profession to upgrade the skills and knowledge of its practising engineers.

The consultants seem divided on the issue of part-time programmes, some saying "such undertakings should be rarely encouraged" and others, "full encouragement should be given to part-time doctoral programmes." ACAP feels that there is a place for the part-time programme and that careful attention should be devoted to designing part-time programmes, bearing in mind the strengths of the departments. One of the dangers sometimes noted is that students become involved, under a part-time supervisor, in a project in an area in which the full-time staff has limited expertise; this is not recommended.

Recommendation C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

Cooperation

One of the main points that all the consultants agree upon is the need for increased cooperation both within and between universities. The chemical engineering consultants found a need for increased interaction between the engineers and the pure science faculties. Some of the other consultants felt the need for more communication and cooperation between the universities and industry and government. Lastly, more effective use could be made of the resources in the province if the universities themselves joined together in some form of cooperative endeavour. CODE endorses this last point quite strongly in its response, page H-4. Sharing of equipment, discipline meetings and an interchange of credits for graduate courses are a few of the methods listed by CODE that are to be encouraged on the way to making this cooperation a meaningful and workable venture. ACAP concurs with the statements made by the consultants and CODE and strongly supports their implementation.

ACAP intends to request that each Discipline Group report regularly to ACAP on interuniversity cooperative arrangements.

Faculty

Two sets of consultants found enough disquieting evidence in the engineering faculties of the province to suggest that the requirements for a faculty member, eligible to supervise graduate students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty with proven research ability and productivity supervise graduate students.

Since this concern has been mentioned in other assessments, ACAP feels it is time that OCGS conduct a review of this area.

Time to Reach Degree

The electrical engineering consultants were concerned about the length of time taken to obtain the PhD. As they pointed out, the average student at one university took 13-20 months longer to complete his doctorate than his counterpart at another university. As a whole, they found the average time of study to be excessive.

Recommendation C9

> It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

IV. UNIVERSITY RECOMMENDATIONS

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

University of Western Ontario

The University of Western Ontario began to offer doctoral work in engineering in 1965. Since then, twenty PhDs in Engineering Science have been granted. From the beginning effort has been made to emphasise its interdisciplinary nature and there has been a limited number of areas in which the student may do his graduate training. At no point has a doctoral degree been given in the so called traditional fields of engineering.

There are seven main research areas in which a student may obtain a PhD in Engineering Science. They are 1. Geotechnical 2. Boundary Layer Wind Tunnel 3. Chemical and Biochemical Process Development and Design 4. Material Science 5. Systems 6. Applied Thermodynamics and 7. Applied Electrostatics. Environmental engineering aspects can be studied in all these research areas except Material Science.

Western's response to the collective engineering picture gives the 1973-74 enrolment as 29 F.T. and 15 P.T. doctoral students. In the additional data given to ACAP, 18 of the 37 current students' programme of study outlined were in the chemical engineering field, 8 were civil, 5 mechanical, and 3 each in electrical and material science.

The chemical engineering consultants have provided evidence of that programme's being of good quality. The systems research area depends heavily on chemical engineering. ACAP, therefore, concludes that the research areas Chemical and Biochemical Process Development and Design, and Systems are of satisfactory quality.

The metallurgical engineering consultants have recommended that the Material Science programme become a part of an interdisciplinary programme rather than an exclusively material science one. This was in part based on the fact that the group is small and spends most of its time teaching at the undergraduate level. They are "carrying a large programme for a group which is subcritical in size." From the additional material supplied by Western, there is little evidence of interdisciplinary activity for students who might be doing research in this area. ACAP concludes that this area should not be operating at the doctoral level.

The areas of mechanical engineering doctoral research work are subsumed under the main research area, Applied Thermodynamics. The consultants indicate that the doctoral research connected with heavy water is of good quality but they raise very serious questions about the doctoral work in acoustics. They feel this area should be restricted to work at the master's level.

The civil engineering consultants did not make comparative judgements, but from some of the phrases used to describe the Boundary Layer Wind Tunnel Laboratory such as "internationally known", ACAP has no reservations in recommending continuance of doctoral work in this research area, even though it appears to have little interaction with other groups. The civil engineering consultants told us nothing about the Geotechnical area and we, therefore, had difficulty in recommending a position to be taken with regard to this field.

The last research area, Applied Electrostatics, is the most difficult to assess. The electrical engineering consultants have recommended discontinuance of the doctoral programme. They feel the students are getting too narrow a training in electrical engineering. We observe, however, that the students are not considered to be studying for a PhD in electrical engineering, but rather for a general degree in engineering science. Although there are only a few faculty members in this area, they are internationally known. The main problem would, therefore, seem to be the extent to which the doctoral training in this area is of an interdisciplinary nature. From the data available to ACAP, we are unsure.

In the course of discussions with representatives of the University of Western Ontario, it became clear that the Faculty is involved in a thorough re-examination of its doctoral programme. It is committed to the concept of an engineering science PhD but is reconsidering the appropriate areas of research. While it is not entirely accepted by ACAP that all the activity is noticeably different from that in engineering departments elsewhere, we nevertheless believe that this intention of the Faculty should be encouraged. A corollary is that it must be very careful about the research areas in which it accepts PhD candidates; we have already commented on these and note the standard of quality seems variable.

These considerations have led us to formulate the following recommendation.

Recommendation C10

> It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

University of Windsor

Early in 1971, the Faculty of Applied Science at the University of Windsor began to examine the structure of graduate programmes within the Faculty in order to improve their operation, avoid needless and costly duplication of graduate course offerings and to attempt to create a greater cross-fertilization of research by involving faculty members from different engineering departments in various facets of a larger research plan. This examination led to the recommendation that Graduate Studies be operated on a divisional basis, with the seven undergraduate departments being consolidated under three graduate divisions, namely Engineering Process Design, Structures and Systems. The three divisions would each elect a chairman who would decide on course offerings and enrolment levels. The three chairmen, one elected member from each division, one graduate student and the Dean of Applied Science form a Coordinating Committee to oversee and coordinate the wishes of the Divisions. This plan was approved in Spring 1972 and is now being implemented.

Some of the traditional departments such as chemical and electrical fall completely in one division. All the rest are split between two as can be seen in the attached Table 1.

There are nine identifiable research areas, each of which have participating faculty from at least two of the old departments and these nine areas are in turn divided fairly equally among the three divisions.

The degrees awarded will retain the old titles, for example, a PhD in Chemical Engineering, but the interaction of the individual student with others in the Faculty will be greatly enhanced. Depending on his research topic, the student might take as many as half his courses from professors in other 'departments'.

The consultants' comments concerning Windsor vary, but a number of their reports imply some doubt or uncertainty concerning the relevant departmental programme, either with respect to the situation at the time of their visit, or in connection with its future direction. The chemical engineering consultants suggest that Windsor be reviewed in greater depth. The metallurgical engineering consultants recommend the integration of engineering materials faculty in the new divisional system. The mechanical engineering consultants call for more emphasis on master's work. In the case of electrical engineering the consultants indicate that good work is now being done in doctoral education in two fields, agree with the present plans for no significant growth in enrolment and for no expansion of fields, and go on to recommend a review after five years.

In view of these considerations ACAP feels the University of Windsor should be given time to produce a viable interdisciplinary system of doctoral engineering studies before that system is brought forward for appraisal. This appraisal would determine the level of quality in the new divisional system and whether or not significant interaction has been achieved between the staff and students of the various departments.

Table I

Organization of Engineering Doctoral Work at the University of Windsor

a. % of Department Involvement in each Division

Department	Engineering Process Design	Structures	Systems
Chemical	100%		
Civil	40%	60%	
Electrical			100%
Engineering Materials	50%	50%	
Industrial	10%		90%
Mechanical	60%	40%	

b. Departmental Research Interests

Research Interests Department	Structures	Electric Power	Thermofluids	Systems and Signals	Human Factors	Mechanical Metallurgy	Physical Metallurgy	Water and Air Quality	Vibration and Noise
Chemical			x					x	
Civil	x		x			x		x	x
Electrical		x		x					
Engineering Materials	x		x			x	x		
Industrial				x	x	x		x	x
Mechanical	x		x	x	x	x			x

Recommendation C11

> It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977 if a favourable appraisal has not been obtained by that date.

University of Guelph

The University of Guelph has for sometime offered an interdepartmental PhD programme in Hydrology in which its Engineering School plays a part. It also plans to develop doctoral work in agricultural engineering, which it already offers at the master's level. There are no other programmes in agricultural engineering in the province.

The matter of the interdepartmental programme would appear not to be central to this assessment. It would not be inappropriate for the Civil Engineering Discipline Group to keep this programme in mind when carrying out the study called for in Recommendation C19. Nevertheless, it seems unnecessary to await the Discipline Group report to make the recommendation which follows.*

From the planning viewpoint, there seems no reason to do other than accept the University's intention to begin doctoral work in agricultural engineering, whenever it feels the time is ripe and the proposal has passed appraisal.

Recommendation C12

> It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

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* It may be noted that COU did not accept Recommendation C19.

V. CHEMICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the chemical engineering consultants' report. There will be no reference made to Western or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C13

> It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

Recommendation C14

> It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

McMaster specializes in process simulation, waste-water treatment, polymer engineering, chemical reaction engineering and catalysis, and transport and separation processes, with stronger emphasis on the first two areas. The consultants feel that McMaster's goals for the future are "realistic" and appear to be "achievable and productive".

Recommendation C15

> It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

The University of Ottawa specializes in three main areas including thermodynamics and transport properties; kinetics, catalysis and reactor engineering; and transport processes. There has recently been a shift towards a greater environmental emphasis. The consultants encouraged Ottawa to keep up with changes in the areas of research and graduate teaching and move into these new areas whenever possible.

Recommendation C16

> It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

Queen's University specializes in the following five doctoral research areas: biochemical and environment engineering, chemical kinetics and reactor design, process control and simulation, thermodynamics, and transport phenomena. These areas cover most of chemical engineering making a rather uniform distribution of effort. The publication records of only two professors are very good, all the rest being average or low. This raises questions as to the activities of the faculty since their connections with professional and scientific societies can be described as "only mildly active". The consultants feel alarm at the number of Queen's bachelor's graduates who undertake graduate work at the same institution.

On the optimistic side, the consultants note that "the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province".

ACAP suggests that Queen's might consider strengthening its present faculty, or alternatively, it might consider consolidating its existing wide scope of research areas. As to inbreeding of students, ACAP draws Queen's attention to Recommendation C7.

Recommendation C17

> It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975 on action taken in regard to this Recommendation.

The University of Toronto lists eight areas of specialization, all of which show a rather uniform distribution of faculty effort. The exception is a marked emphasis on applied chemistry. The consultants would like to see an effort to group the staff in given areas of research instead of the present policy of allowing a staff member "to select his own path". The consultants did not find Toronto's statement on its plans particularly helpful and they offered no comment on it, other than to say that "it is doubtful whether any increase above the present enrolment would be beneficial to these new students or to the student body as a whole". The University of Toronto should also encourage mobility of its graduates to the benefit of other departments and of the students alike.

Recommendation C18

> It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

The University of Waterloo has grouped its research activity into five areas including biochemical and food engineering, extractive and process metallurgy, polymer science and engineering, mathematical analysis and control, and transport processes and kinetics. The scope is wide, covering a large part of chemical engineering but, there are defined groups to coordinate the programmes. Although the consultants considered the statement of goals and objectives "less positive and definitive" than others, they were pleased to note Waterloo's intention "to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary".

VI. CIVIL ENGINEERING

The report of the civil engineering consultants contains a number of important recommendations of a general character.

Their discussion of the manpower situation supports our Recommendation C1. They suggest that it would be wise to expect rather fewer students than the totality of the stated university plans. Considering the uncertainty of the manpower analysis and the size of the numbers involved, ACAP does not feel it desirable to formulate any recommendations about individual enrolment. ACAP does advise each university to consider the likelihood that the doctoral enrolment in civil engineering may fall still further unless the fraction of Canadian students increases substantially from its present level of about 25%.

Their comments that the "study of a civil engineering speciality in depth necessitates increasingly...some graduate work", reinforces our Recommendation C2 concerning publicizing the value of graduate work.

They argue for more part-time work and closer liaison with industrial and governmental laboratories. Recommendations C2 and C8 touch on this point.

The consultants on pages A-18 and A-35 express their concern that students tend to remain for graduate study at their undergraduate universities, often being unaware of offerings elsewhere. We make recommendations on this problem in Recommendation C7.

The consultants perceive a need for "more consistent requirements of acceptance....between universities". Although we do not recommend the particular remedy they suggest we do make Recommendation C4 in this connection.

On matters specific to civil engineering, the consultants stress the need for more emphasis on fields other than structures. They call for less stress on "traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation". They suggest that "change of programme emphasis in civil engineering (will) lead to some growth in faculty when generally universities are expecting a fairly static period". On pages A-49 and A-50, they quantify this shift by asking for a 20% reduction in doctoral enrolment in structures (i.e. a drop of about 15 students) together with a corresponding increase, roughly equally in transportation and water resources. Perhaps rather surprisingly they then suggest that no university should offer a new field at the doctoral level. (On page A-52 they also suggest that no university reduce "the range of its doctoral programmes" but on page A-51 they add "unless that university desires otherwise".)

The consequence of this stance, based on pages A-25 to A-29, is summarized in Table 2.

Table 2

CIVIL ENGINEERING

Possible Consequences of the Consultants' Recommendations on Enrolment and Field Emphasis

Universities	Fields				Order of Magnitude of Enrolment
	Geo-technical	Structures	Water Resources	Transportation	
Carleton	S	R	-	I	6
McMaster	-	S	I	-	10
Ottawa	S	R	I	-	17
Queen's	S	R	-	-	8
Toronto	S	R	I	I	25
Waterloo	S	S	I	I	30

LEGEND: R - reduce enrolment
S - static enrolment
I - increase enrolment

NOTE: Guelph, Western Ontario and Windsor are not included in the chart as they are dealt with elsewhere. (See section on University Recommendations.)

There are difficulties in accepting these recommendations. For example, if one asks what the shifts of enrolment from structures would be, to total around 15, one comes up with something like: Carleton 2, McMaster 0, Ottawa 3, Queen's 2, Toronto 4, Waterloo 4. Looking then at transportation one finds doctoral programmes at Carleton, Toronto, and Waterloo which might increase by 2 or 3 at each place. One has to ask if this is the best way to develop more high quality doctoral work. Would it be a better strategy to encourage Carleton, for example, to build a somewhat larger group than 3 or 4 students? There is another concern. Are all the transportation groups of equal promise as places to do doctoral work? If not, should some be strengthened more than others? If we really believe in penny-packet enrolments, could a fourth university perhaps enter this field? The consultants' report provides no satisfactory discussion of these questions to justify its proposals.

Equally unsatisfactory, and perhaps more basically disturbing, is the consultants' failure to give any discussion whatsoever (with three small exceptions) of the facts and reasoning which led them to conclude that all existing programmes are satisfactory. This may be so, but the rationale is far from clear. As the appended correspondence (Appendix 1 to this section) shows, the consultants decline to discharge their terms of reference, in particular C3c and the paragraph following C3d. (See Appendix D).

In particular, although the matter of critical academic enrolment size is discussed in generally acceptable terms, in that the proposition is stated that there is no a priori reason to assume a small school cannot provide as satisfactory an environment for a PhD student as a big school, the consultants neither state the characteristics of such an environment nor do they make any effort to show that it exists in the several small programmes they examined. Although it is no doubt possible to make the justification in several cases, nevertheless a question must still loom unsettled as to the academic strength (from the potential students' viewpoint) of several of the programmes, namely Carleton, Guelph, McMaster, and perhaps Ottawa and Queen's. (None has been appraised.) Of course the consultants' report, due to the lack of rationale in it, gives no reason to suppose that the larger departments are necessarily of suitable quality either.

ACAP cannot justify to itself recommending the acceptance of the consultants' plan, calling as it does for static enrolment, small shifts of emphasis in fields, and no new developments in any department. We feel that the question of the best way to develop doctoral work in transportation and water resources must be more carefully canvassed and that whatever the answer be it must be adequately justified. Some evaluation of the quality of the programme in each broad field at each university must be available before we can make any credible recommendation.

ACAP would like, at this point, to draw attention to the Discipline Group's response, Appendix B. The members of the group feel the consultants did not "seize their unique opportunity to make quality judgements" and failed to "address themselves to the question of quality in the planning function in their conclusions and recommendations." The group thinks that a statement that "documents the sundry strengths and weaknesses, if they exist, could well increase the value to those on whom the responsibility for planning ultimately rests". ACAP therefore makes the following recommendation.

Recommendation C19

> It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

We regret that this recommendation is necessary. We note (page A-5) that the Discipline Group had not prepared for the consultants the report called for by the agreed procedure (page D-6). We note also that the consultants state that they "have formed (their) own judgement about the strengths of different civil engineering departments and the areas in which they are likely to be able to attract high quality students" - we regret that the consultants are not willing to share these judgements with the Ontario university community which employed them.

APPENDIX 1

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

21 February 1974

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

Further to our recent telephone conversations, I have now heard from all my colleagues who fully agree with my letter to you of 4 December 1973.

As mentioned in this letter, we did not discuss the question of quality in our Report since none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

Moreover, we did not feel the need, nor were we required by our terms of reference, to make relative quality judgements regarding the strengths or weaknesses of individual areas or departments, because in our Report we did not recommend any change in the number or the range of doctoral programs offered by any school, including the various areas of specialization of the smaller universities.

Since the civil engineering discipline group, as well as most universities, find our Report on the whole acceptable, we think that little is gained by getting into an area which might be interpreted as an appraisal or accreditation assessment.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb
c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

4 December 1973

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

After returning from the west coast, I found your letter of 29 November and enclosures, which I read with interest.

In reply and following our terms of reference, we had not discussed the question of quality in our report since, in our opinion, none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

I am looking forward to the comments of my colleagues, in this regard.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb

c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
102 Bloor Street West, Toronto 181, Ontario
(416) 920-6865

Postal Code: M5S 1M8

November 29, 1973

Mr. B. V. Martin
Prof. G. G. Meyerhof
Prof. W. W. Eckenfelder, Jr.
Dr. J. L. Boulet

Gentlemen:

I am enclosing all the university comments we have received on your planning assessment report and the formal response from the Discipline Group. You will recall that it is intended to publish these statements.

You will see from the comments that there is considerable dissatisfaction in the universities and in the discipline group with your failure to come to terms with your task of giving us your findings on the relative quality of the doctoral work in the different areas of civil engineering in the different departments. We on ACAP have to agree that one of the most important aspects of the terms of reference you undertook is the statement of strengths and weaknesses of departments, and that without it the report lacks credibility. If you are asserting that all fields offered for doctoral work are competently dealt with wherever they are offered, it will follow that civil engineering is a paragon amongst disciplines. Even if true, it does not help the universities to decide which areas to strengthen.

In one of the few specific comments, you do suggest that McMaster should emphasize earthquake engineering. Do you think its work in water resources is strong enough that it should seek to expand or maintain that, or, when you recommend greater emphasis on water resources, do you expect this to be achieved at Ottawa, Toronto, Waterloo and Windsor for example? McMaster (and the others) would like to know. You tell the University of Western Ontario to emphasize boundary layer wind tunnel work; but what about their geotechnique? Since Guelph now has 5 students in its hydrology programme, how can it be exploiting its unique facilities for agricultural engineering if its enrolment becomes 4 to 7? Is it expected to cut back on hydrology? To consider this, it would be necessary to know how valuable Guelph's hydrology work is and how substantial is the potential of its agricultural engineering programme.

I mention these points only as examples of the kind of question on which your adivce would be helpful. The general point is that your judgements of quality by department and by area are important. You recommend that transportation be strengthened; we ask, where? If all the departments say "here", how are decisions about resource allocation to be made without the quality judgements you were expected to give?

....2/

One of the aspects of academic quality has to do with the size of the student enrolment. You will see from the university responses that there is some difference of opinion. The official position of COU, recently adopted, is as follows:

"The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design."

Recommendation 4 on page 52 of your report is not inconsistent with the above statement, but you do not indicate what criteria determine the "satisfactory environment." In ACAP we have identified two areas which we believe should be examined in this connection. One is the opportunity for the students' development through informal intellectual discussion with a peer group with common engineering or scientific interests. This peer group need not consist only of students; it may also include post-doctoral fellows. It need not be confined to one department, but may include students in other departments if there is a real sharing of research interests. The second main area for consideration has, we feel, to do with graduate courses. Assuming that a course with, say, 5 or 6 students who interact is a much more satisfactory experience than one with 1 or 2 students, we see that the desirable enrolment size is a function of course structure. If there were a programme which did not require courses, this second criterion of size would not apply. But if it is felt that students should take a substantial number of courses (as appears to be the case in all the Ontario departments), then the consideration is valid and the situation needs examination.

It appears that some of our departments plan enrolments as small as 6 to 12. It may be that some of these departments, because of specialization, course structure, post-doctoral and master's population and interdepartmental collaboration, offer an academically sound experience for the student, while other departments with the same enrolment may not. Each case needs evaluation separately.

This brings us back again to the desirability of your giving a detailed analysis of each university. We request evaluation of quality by area of study of each department, including an analysis of the kind of intellectual milieu established for a student by the enrolment size.

I hope you realize that we have a problem of reconciling the reports of the consultants on the various engineering disciplines. One report of which there seems to be pretty general approval is that dealing with electrical engineering. Of course not all its details are accepted by everyone, but the style and coverage of the report has not been attacked. I enclose a copy, since it may make clearer what I have been trying to say in this letter.

After you have had a short interval to consider the letter, I shall telephone Professor Meyerhof to discuss the mechanism of your response. We need your assistance.

Yours sincerely,

M. A. Preston

MAP/cew
Enclosures.

VII. ELECTRICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the electrical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C20

> It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

Other Discipline Groups might also consider this recommendation.

Recommendation C21

> It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

The work in electrical engineering at Carleton is divided into two departments, Electronics and Materials Engineering which includes solid state device electronics, circuits and circuit theory, microwave electronics and electron beam systems and processes and the Systems Engineering programme which concentrates on information systems such as communications and signal processing, decision and control, digital systems design and software engineering. The coverage within these two areas is well integrated, coordinated and appropriate for PhD training. The enrolment increase proposed by Carleton is within the competence and capability of the present staff.

Recommendation C22

> It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

McMaster has outstanding strength in three areas of graduate research and has plans to strengthen a fourth. These are communications and data processing, modelling and design, materials and devices and, lastly, medical electronics. The electrical engineering programme at McMaster is of high quality, with a productive and dynamic faculty.

Recommendation C23

> It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

The department at Ottawa specializes in three areas, communication systems, control and systems, and computer engineering. With a faculty of 11, the consultants felt that they were spread over a rather large area of electrical engineering. A small department with a small number of staff and students can operate an effective doctoral programme only with competent professors, complementary fields of study and an adequate research environment. The consultants recommend discontinuing the programme. ACAP has considered both the consultants' report and the university's comments and has concluded that Ottawa has a contribution to make to graduate electrical engineering study in operating a specialized programme of limited scope and enrolment.

Recommendation C24

> It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

The areas of specialization at Queen's are communications, systems, electronics, and energy processing. The consultants state that the work in communications is good but is only fair in systems, and that the Department should not offer a programme in the latter two fields on a regular basis. However, we suggest that an occasional student be allowed to do a thesis in one of these fields. ACAP accepts the consultants' view about enrolment which was made on academic grounds, not for planning reasons.

Recommendation C25

> It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

Graduate work at the University of Toronto covers seven areas including communications, computers, control, power devices and systems, solid state electronics, wave sciences, and biomedical electronics. The coverage of these fields is more than adequate and Toronto's "star-studded" faculty are spread over the seven areas indicating significant breadth across the department. The consultants conclude that the Toronto department compares favourably with any of the major institutions in North America.

Recommendation C26

> It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

The University of Waterloo concentrates in five major areas including computers and communications; control, systems and networks; devices, circuits and materials; power engineering; and, antennas and electromagnetic engineering. There are two minor fields, bioengineering and electroacoustics, and these fields should be limited in size to the present level of activity. With Waterloo's highly competent faculty and well-equipped facilities, there is no question that the enrolment level planned by Waterloo can be accommodated.

VIII. MECHANICAL ENGINEERING

There are a number of general recommendations and comments made in the mechanical engineering consultants' report that are aimed at the system as a whole. Recommendations for the individual universities follow this more general section.

The mechanical engineering consultants do not anticipate any oversupply of mechanical engineers. They believe no "artificial edict" is necessary to control the number of PhDs. On the contrary, they suggest the problem will be one of availability of good students. The consultants think that Ontario might, in fact, have a shortage of mechanical engineers.

"Traditional classical" versus "applied" research projects and a shift in emphasis of study are the next problems attacked by the consultants. They feel that the doctoral education of today should shift more towards project and design activity. To this end, they advocate increased dialogue and cooperation with outside agencies such as industry and government. "If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front". The consultants also recommend a change in emphasis in fields of study. Some areas of research that need to be developed are listed on page A-14.

The consultants do not condone departments that attempt to be good in all fields. They feel specialization is the key and that "considerable selectivity is required in the choice of a particular area of concentrated effort". This choice of areas of concentration should be left up to the universities. ACAP agrees with this outlook but notes that the initiatives of each department in Ontario are matters for collective consideration and advice. ACAP advises the departments to consider the consultants' suggestions noted in the addendum and asks that they report on progress made after a year of mature consideration. After this time, the Discipline Group, in its normal role, would continue to consider the development of new areas of graduate study and the possible entry into neglected fields in mechanical engineering in Ontario and would make recommendations to ACAP where change is desirable.

Another problem the mechanical engineering consultants addressed was the one of faculty age. Since the Ontario universities have been through an expansionary period in the sixties, a large proportion of the faculty is below 45 years old, consequently lacking something in maturity and industrial experience. The consultants feel that although the retirements in the next several years will be few, the universities should take these opportunities to introduce new blood by appointing faculty with industrial experience.

It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendations

Recommendation C27

> It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

The Mechanical Engineering consultants, in their addendum, give valuable suggestions for focussing research activities in each department. These suggestions appear to be based on both planning grounds and grounds of academic quality, but alternative research foci may not be ruled out. Consequently, ACAP recommends that the three doctoral programmes continue but that each university note the consultants' comments and report on progress in a year's time.

Recommendation C28

> It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

The consultants, in their remarks concerning the University of Ottawa, page A-17, recommend that the work in the Mechanical Engineering Department be incorporated in an interdisciplinary programme leading to an undesignated PhD degree. ACAP notes the university response, page C-14, which states that they wish to "reactivate" the doctoral programme, before discussion of this new proposal. We do not at this time make a recommendation on the future form of engineering PhD work at the University of Ottawa. There appear to be no planning reasons why there should not be a programme at Ottawa in mechanical engineering, but the consultants have serious reservations about the suitability of a number of the research projects of the department and about the limited industrial experience of its staff members.

Recommendation C29

> It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

We draw the attention of the University of Toronto to the consultants' suggestion that the Department of Mechanical Engineering concentrate research on problems of major, national concern. UTIAS should note the consultants' comments on the need for selectivity within the broad spectrum of the expertise of the staff, in such areas as plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. The consultants also favour increased interaction with work in related fields on the main campus.

Recommendation C30

> It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

ACAP notes the consultants' suggestion that the department concentrate in Production and Automation. We also take note of Waterloo's response which lists strengths in other areas. We recommend that Waterloo consider the consultants' idea of developing foci of research interest and report on any action thought desirable.

The University of Western Ontario and the University of Windsor have not been discussed here, since there is no need for any recommendations in addition to those in the section on University Recommendations, page 20.

IX. METALLURGICAL AND MATERIALS ENGINEERING

This section of the ACAP report will deal with the recommendations found in the metallurgical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C31

> It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these reommendations.

The consultants find it surprising that there is so little effort in the ceramics and glasses fields of study. Even more striking to them is the absence of any work in polymers in the Departments of Metallurgy and Materials Engineering. In their first few recommendations, they consider it very important to rectify these neglected areas and ACAP feels this is a job for the Discipline Group. They also feel it is important to strengthen already existing areas of study and in particular create at least one internationally-known centre of materials science activity.

Recommendation C32

> It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:
>
> a. recruitment of students with physics and chemistry backgrounds
>
> b. strengthening of the extractive metallurgy faculty
>
> c. collaboration with Toronto

The materials science programme at McMaster is considered by the consultants to be the best programme of this kind in Ontario and probably in Canada. It is the only programme that covers adequately the basic science related to all classes of materials including polymers. The enrolment could be easily doubled without developing the need for any significant increase in resources allocated to the programme, but enrolment, here, is limited as in so many other areas of engineering, by the number of qualified students.

The extractive metallurgy programme, although not as strong as the materials science one, provides very suitable research for the doctoral thesis. The range of the programme is, however, inadequate but cooperation with other McMaster Departments and with the University of Toronto will greatly enhance the operation of this programme.

ACAP suggests that McMaster consider the points put forward by the consultants and that the university report to ACAP on any action taken with regard to these recommendations.

Recommendation C33

> It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975 if a favourable appraisal is not obtained.

The consultants consider the programme in physical metallurgy at Queen's a good, traditional type of programme taught by young and talented faculty. Although it would make a suitable base on which to build a programme in materials engineering, the consultants do not recommend that Queen's do so.

The programme in extractive metallurgy, on the other hand, is not so well off. It is seen by the consultants to be inadequate in its present form, with too small a range of courses, too limited an amount of research activity, and ineffective interactions with other departments and programmes. But the consultants feel it is necessary to strengthen and develop this field, to provide the needed PhD graduates and maintain Queen's part in a history of leadership in Canada in mineral engineering, geology and related fields.

The enlarged programme of extractive metallurgy is envisaged by the consultants to consist of support from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology. ACAP realizes that cooperation cannot be legislated, but it must have some formal structure in order to make the various professors aware of their part in a cooperative venture and secure the recognition of their departments for the effort devoted to the venture.

Recommendation C34

> It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975 on any progress made in this direction.

Toronto has an international reputation for its graduate work in extractive metallurgy. However, the range of courses is limited; this situation could be improved through cooperation with McMaster. The consultants feel this would provide a good base from which to develop a programme in mineral engineering and extractive metallurgy and they advise the university to do so.

In addition to those who work in extractive metallurgy there is another group of professors in the department who describe their work as physical metallurgy and materials research. These people working with added specialists in polymers and electrical and optical properties of materials would form a group capable of mounting a substantial programme in materials engineering.

Recommendation C35

> It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Waterloo has no specific programme in materials and does not offer a PhD labelled as metallurgical engineering or any allied field. Instead, students are trained in extractive metallurgy in the Department of Chemical Engineering and there is a group of metallurgists and materials scientists in the Mechanical Engineering department. The consultants felt their effort was of such high quality that if this group were constituted as an administrative unit, they would be the strongest and most comprehensive graduate programme in materials engineering in the province. The consultants recommend setting up a separate administrative structure. However, the unit (all in one department) appears to function well without separate administration and ACAP does not feel that such a structure is imperative. Waterloo will, no doubt, consider the consultants' suggestion.

X. MINING ENGINEERING

Queen's University offers the PhD in mining engineering. This is unique in the province. Although the enrolment is small, the programme appears to fill a distinct need. The University projects no enrolment increase, showing only 4 students in 1977-78.

On the basis of the statement of future plans made by the University, we recommend:

Recommendation C36

> It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

XI. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

This section of the ACAP report will deal with the recommendations found in the industrial engineering and systems design consultants' report. It will contain recommendations on the Universities of Toronto and Waterloo. ACAP suggests that the University of Windsor take careful note of the recommendations made in this consultants' report but at this time ACAP makes no specific recommendations on doctoral work in industrial engineering at Windsor since it is part of the earlier Recommendation C11.

The general recommendations in this report echo many of those found in the earlier consultants' reports. These consultants' estimates of manpower supply and demand closely follow those made by the other consultants and are discussed more fully in the second part of this ACAP report. Related to this is the need to increase the Canadian content in engineering programmes. Recommendations C1 and C3 refer specifically to these two points.

ACAP notes that the universities do not consider the establishment of a co-ordinating committee to be very important. We hope that talks are normally taking place between the three departments and that they will continue. ACAP feels there is no need to set up a formal Discipline Group to ensure discussions but if those concerned wish to do so it can be arranged.

Again, as in the other consultants' reports there is seen to be a need to circulate information to the student concerning the various programmes in order to ensure he selects the programme best suited to his objectives. This problem has been addressed by Recommendation C7.

ACAP endorses the consultants' recommendations 6,7,8,9 and 11 and does not wish to make any particular comments on these recommendations.

Recommendation C37

> It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

In its response to the consultants' report, the University of Toronto seems in general agreement with the recommendations made concerning its programme. ACAP notes that the Department has already made the appointment suggested in recommendation 3.

As far as future enrolment is concerned, ACAP suggests the university continue to expect approximately the same enrolment as it now enjoys. In accordance with standard appraisal procedures, a shift in fields of specialization to programmes in health systems and energy systems would require referral to the Appraisals Committee to determine whether or not an appraisal is necessary.

A review of the enrolment expectations would be made at that time. For the present, a continued output of 3 or 4 PhDs a year should be expected by the university. This should not be regarded as a quota but rather as the outcome of the present situation of fewer qualified students and falling enrolments. It should be noted that the University of Toronto has maintained a high percentage of Canadians in its industrial engineering programme in comparison to other engineering programmes both in the University of Toronto and elsewhere.

Recommendation C38

> It is recommended that the University of Waterloo continue its doctoral programme in systems design.

ACAP takes note of the response of the University of Waterloo to the consultants' various recommendations concerning the Department's isolation, its "soft" course content and the quality of recent staff appointees. Despite the possibility that enrolments may increase in this field and despite the comments from the University, ACAP considers that Waterloo should give careful attention to the consultants' recommendations for strengthening the programme before increasing the enrolment.

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APPENDIX A

REPORT OF
METALLURGICAL AND MATERIALS ENGINEERING
CONSULTANTS

to

ADVISORY COMMITTEE ON ACADEMIC PLANNING
COUNCIL OF ONTARIO UNIVERSITIES

Dr. J. J. Jonas, McGill University
Dr. T. B. King, Massachusetts Institute of Technology
Dr. W. B. Lewis, Deep River, Ontario
Dr. W. S. Owen, Massachusetts Institute of Technology

September, 1973.

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RECOMMENDATIONS

The principal recommendations of the consultants are as follows:

General

We recommend that, relating to doctoral programmes in the Province of Ontario:

1. The substantial effort in extractive (chemical) metallurgy already existing in some universities in Ontario be further strengthened.

2. At least one of the existing programmes in materials science be strengthened to ensure that there will remain in Ontario a materials science activity of international stature.

3a. Wherever viable programmes in metallurgical, ceramic or polymer engineering exist they be combined and augmented to develop strong programmes in materials engineering.

3b. The proportion of the effort in materials engineering devoted to ceramics and glasses be increased.

3c. At least one materials engineering department be established or expanded in an Ontario university to develop a strong programme in polymeric materials integrated with a general materials engineering programme.

We recommend that:

1. The figures for anticipated demand in 1974-75 for PhDs in Ontario in 'mining, metallurgy and materials' be at least double those given in Table 58 of the report of the Canadian Engineering Manpower Council, July 1973, and the targets for the total PhD student population in these disciplines be adjusted accordingly. Most of the necessary substantial increase in the output of PhDs should be from departments with comprehensive programmes in materials engineering or materials science or both.

2. Efforts to recruit a larger proportion of the PhD students from the graduates of Canadian undergraduate programmes should be continued and intensified. The stipends paid to Canadian graduate students are inadequate to attract a sufficient number and should be increased substantially.

We recommend that graduate programmes available to students entering materials science and materials engineering from other undergraduate programmes should be designed to make the transition as meaningful as possible, and also to attract students into the subject area. Graduate programmes should be examined with this objective in mind.

Individual Universities

McMaster

We recommend that the preeminent position in Canada of the materials science programme at McMaster University be recognized. The programme should be expanded and the efforts of the faculty members to recruit good students from undergraduate programmes in physics and chemistry should be supported energetically.

We recommend that the programme in extractive metallurgy at McMaster University be strengthened by adding one faculty member and by increasing the participation of appropriate faculty members from the Department of Chemical Engineering. Collaboration with the complementary extractive group at the University of Toronto should be continued and extended.

Toronto

We recommend that the outstanding programme in extractive metallurgy at Toronto be recognized and used as a base from which to develop a larger and broader programme in mineral engineering and extractive metallurgy.

We recommend that a full-scale graduate programme in materials engineering be developed at the University of Toronto by the addition of faculty members in appropriate specializations to the Department of Metallurgy and Materials Science (which should change its name). Cooperation with faculty members in other engineering and science departments who have an interest in the application of materials should be developed and expanded.

Queen's

We recommend that:

1. The programme in extractive metallurgy be replaced by an enlarged programme in extractive metallurgy and mineral engineering developed jointly by faculty members from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology.

2. The PhD programme in physical metallurgy be maintained.

Waterloo

We recommend that the Faculty of Engineering be urged to reexamine the proposition that some administrative and organizational structure be developed to give coherence and visibility to a graduate programme in materials engineering.

Western Ontario

We recommend that the graduate effort be directed towards the development of strong interdisciplinary centres rather than an exclusively materials science programme.

Windsor

We recommend that the efforts of the faculty members of the Department of Engineering Materials to integrate their graduate work with that of the Divisions of Structures and of Engineering Process Design should be encouraged and supported financially.

We recommend that more attention be given to interuniversity cooperation in the Metallurgy and Materials field in Ontario: such collaboration could take the form of coordinated course transfer at the graduate level, of the use of a TV talk-back network for graduate instruction and seminars, and of the shared construction and operation of expensive research facilities.

INTRODUCTION

The study group directed by Philip A. Lapp reported in Ring of Iron: A Study of Engineering Education in Ontario (December 1970) that they were concerned over the rapid growth of PhD studies (in engineering) in Ontario. Of the 1893 graduate students (enrolled) in 1969-70 more than 600 were doctoral candidates. They recommended that the total number of such students in the system not exceed 450 by the year 1973-74 and remain at that figure until updates at the next review. The recommended distribution of the doctoral enrolments is listed in Table 10-4 on page 69 of the report. For the six universities of interest in the present study of metallurgy and materials programmes, the PhD enrolments in engineering for 1973-74 recommended by the Lapp report are 390, i.e., McMaster 45, Queen's 55, Toronto 165, Waterloo 125, Western 0, Windsor, 0. The report does not break down the figures to indicate the number to be enrolled in the different engineering disciplines. Clearly, the recommendation is that PhD programmes related to materials in Western and Windsor should be eliminated along with other engineering programmes of these universities.

In their response to the 1970 Lapp report the Committee of Ontario Deans of Engineering (CODE) supported the reduction of the total full-time PhD enrolment in the system and accepted a level of 450 as being reasonable for the year 1974-75, having regard for the current utilization of PhD graduates. However, they did not accept the recommendation that PhD programmes be eliminated at both Western and Windsor. They expressed the view that the future of these, as of all PhD programmes in the system, should be determined on the basis of academic quality and demand.

The Council of Ontario Universities (COU) felt that the Lapp report did not fully document the figures given for individual universities in Table 10-4 (page 69) of the report, nor were they satisfied with the reasons given for the elimination of certain doctoral programmes. COU agreed with CODE and OCGS (Ontario Council on Graduate Studies) that attention must be given to the number of doctoral candidates by disciplines as well as by universities. In their report of October 1971, written in response to the 1970 Lapp report, the Council of Ontario Universities recommended that, for the year 1972-73, doctoral enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates, (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing the PhD enrolment (by limiting new entrants to PhD programmes to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments, respecting PhD programmes, to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand, and quality correlates, and are to be used to provide specific recommendations on changes in the total PhD enrolment and the division of the enrolment among universities and disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73 and to recommend a mechanism for continuing review of the PhD enrolments. Assessment procedures were worked out by ACAP in cooperation with CODE, in terms of which engineering discipline groups were established. In March 1972 the COU approved the procedures and terms of reference which ACAP and CODE recommended.

This is the report of the consultants to the 'Metallurgical Engineering' Discipline Group. By their terms of reference, the consultants were asked to 1) consider the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks assigned to them, 2) report on the adequacy of the present state of doctoral work in 'Metallurgical Engineering' in the Province of Ontario, in general and in each university where applicable, 3) make recommendations for the development of doctoral work in the fields of this assessment, in Ontario, between 1973 and 1978. The terms of reference are set out in detail in Appendix 1.

INTERPRETATION OF 'METALLURGICAL ENGINEERING'

Traditionally, metallurgical engineering encompasses two main branches, extractive metallurgy and physical metallurgy. While extractive metallurgy has remained a well-defined discipline, physical metallurgy has merged into the growing engineering science concerned with the whole range of materials of interest to engineers. These materials include metals, ceramics, glasses, polymers, electronic materials, composites, materials developed specially for their optical properties, magnetic materials, and others. In modern programmes about materials, attention may be focused on the basic science common to all such materials or upon the technologies and engineering application of one or more different types.

It has been found to be convenient to subdivide the study of engineering materials into two parts, materials science and materials engineering. Many departments in engineering schools carry one or both of these designations in their title. We will adopt the simple view that the activities of the faculty and students in the departments under consideration can be described as either extractive metallurgy, materials engineering, or materials science.

There are in most universities, in addition, professors and students working on materials, scattered amongst many departments of engineering and pure science faculties. They are to be found in departments of applied mathematics, physics, chemistry, environmental science, biological sciences, and a whole range of earth and space sciences. In addition, there are many engineers concerned primarily with materials problems who are working in departments of engineering other than those designated as materials departments. All of these scientists and engineers can be described as specialists in a specified discipline with particular interests in materials, in contrast with scientists and engineers working in materials departments, who have a primary interest in materials and a special interest in the application of materials in engineering. While we interpret our terms of reference to mean that we should focus on materials departments and groups, we have considered it necessary to take account of the activities of many faculty members working in associated fields.

Extractive metallurgy has developed because of the unique nature of the processes and problems of the primary metal-producing industries. While much of the content of the discipline is specialized high temperature chemistry, extractive metallurgists are concerned also with hydrometallurgy, problems of heat and mass flow, and the unit operations in systems of a kind familiar to chemical engineers. The nature of the developing technology is much influenced by the raw materials available and the skills and limitations of mineral engineers who prepare this material for chemical extraction. Thus, it is important that extractive metallurgists work in association with inorganic chemists, chemical engineers, and mineral engineers. It is probably also important that there be some connection with industrial engineers and economists.

Extractive metallurgists, metallurgical engineers and physical metallurgists are often found together in the same department. Historically, this association was considered desirable because the physical metallurgist was dealing with metals and alloys, many important properties of which are sensitive to the chemical, thermal, and mechanical history of the materials, while the extractive metallurgist and the metallurgical engineer were concerned with an important phase of that history. In the early development of steel the level and distribution of impurities remaining in the steel after ingot solidification were found to have a large effect on the mechanical and physical properties of the steel after it had been fabricated. Whilst the importance of impurity levels and distributions is still a topic of vital interest in relation to many engineering materials, the materials scientists and the materials engineer have, in recent years, concentrated their attention to a much greater extent on the structure-property relationships, particularly as these are affected by solidification and thermomechancial fabrication. The ties between the extractive and physical metallurgist have, as a consequence, progressively weakened. Because extractive metallurgists have a special knowledge of the relevant high-temperature chemistry, many have been very effective in research on high-temperature oxidation and corrosion, a subject of vital interest to physical metallurgists. Some extractive metallurgists have also maintained an interest in solidification, particularly in segregation, a subject of equal interest to many physical metallurgists. However, there are surprisingly few departments in which these common interests have been an effective cohesive force. Although it is usual to find extractive metallurgists associated with physical metallurgists in departments of metallurgy, there seems to be no compelling reason for preferring this association over, for example, the association of extractive metallurgists with chemical engineers. While it would be possible to have an extractive metallurgy group without any connection with physical metallurgy, such isolation would be undesirable. However, it is feasible, and sometimes by force of circumstances necessary, to have sound physical metallurgy, materials engineering or materials science without any interaction with extractive metallurgy.

The great importance of primary industries in the economy of Canada needs no emphasis. There are strong undergraduate programmes in extractive metallurgy in four or five universities in Canada and a significant effort in a number of others. The total effort in Canada is, proportionately, substantially greater than in the United States, the discrepancy reflecting the difference in the relative importance of primary industries in the two countries. The Canadian undergraduate programmes appear to have been successful in supplying technologists, supervisors, and managers for the extractive industries. Only a few university departments of metallurgy in Canada have developed significant research programmes in extractive metallurgy and, consequently, they have not graduated many PhDs who have found employment in the research and development sector of Canadian firms working on the extraction of metals and alloys. To some degree, the Canadian mineral industries rely upon their own research and development effort. There is, however, a pronounced emphasis on short-term research. The need for the scientific sophistication expected of a PhD graduate appears to be small, but this is a situation which is likely to change radically in the next few years. Economic survival will dictate that a bigger proportion of the industries' resources be devoted to basic as well as to short-term research.

Materials Science, as a concept, has received much attention, particularly in the United States, during the last dozen years or so. The basic fact is that the science relating to individual classes of materials is, in large measure, the same for each class of material. The nearer one gets to pure science, the more homogeneous the discipline becomes. The basic material sciences are solid-state physics and solid-state chemistry and these are obviously unified disciplines. In the past, physical metallurgy, physical ceramics, and physical polymeric science developed quite separately because the extractive, thermal and mechanical processing were found to be of overriding importance in determining the properties of the finished product. Many years ago physical metallurgists gave a lot of attention to the difference in properties between Bessemer and open-hearth steels. Much of the content of courses in engineering ceramics was concerned with the origins of ceramic materials and the effect of processing upon them. Similarly, the newer interest in polymer engineering has been demonstrated by studies of the effects of various processing treatments on the properties of the polymers produced. Immediately after the second world war it was realized that a useful and intellectually satisfying understanding of the effects of various kinds of processing upon the properties of materials in general could be obtained by a study of the detailed structures of the materials, as they are affected by processing, and the relationships between these structures and the physical properties of interest to the engineer. Thus, the central theme of materials science is the relationship between structure and properties. It is this which provides the unification of the constituent subdisciplines. Structure is defined in broad terms to include the structure of electron densities, atomic arrangements, submicroscopic arrangements of atoms, molecules and defects, as well as microscopic and macroscopic structure. The properties of interest are selected by the engineer from a wide range of physical properties. The list should include some properties of potential interest, although they may not find widespread engineering application at the present time.

All machines and structures have to work in a gaseous or fluid environment. Study of the effects of the environment, particularly surface degradation effects, comprise an important part of any scientific study of materials developed in an engineering context. It is found that many of these phenomena can be understood by consideration of the interrelationships between the structures of the solid materials and the environments in which they operate. It might be argued that the subject areas defined by taking the structure-property approach are in fact simply areas of physics and chemistry and that materials science is an interdisciplinary study of materials. In large measure this is true. There are, however, areas of science of central importance to materials science which fall between physics and chemistry and which tend, therefore, to be of relatively little interest to either of the basic sciences, or which are areas of physics in which the professional physicist has neither interest nor competence. Materials science is an applied science which grows out of the engineering experience. The phenomena of interest and the problems demanding attention are identified by this experience. Although it is an applied science, materials science is by definition a science and not a technology.

The graduates of PhD programmes in materials science are employed by universities and by research laboratories of government departments and industries directly involved with the advancement of sophisticated engineering. Materials scientists find the Bell Telephone Laboratories at Murray Hill, New Jersey, to be an ideal place in which to work, but they are not likely to be found in significant numbers in the technical department of a cast iron foundry. In Canada, secondary production industries have been developing over the past few decades but they are not of the relative magnitude found in the United States or Europe. Thus, at first sight, it seems that the need for PhDs in materials science in Canada is small. There are in Canada, however, several expanding industries based upon modern science-oriented technologies. AECL and some of the government laboratories employ substantial numbers of materials scientists. Materials science underpins all of the work of the materials engineer concerned with a specific materials technology. Being a science, materials science is international and clearly the materials engineer in Ontario will benefit from the total body of knowledge in materials science, irrespective of the origins of that knowledge. There are, however, several reasons why Canadian universities should participate fully in the development of materials science. The subject is an essential component of the education of all engineers who are to be associated with materials. Consequently, if materials science is to be taught at the undergraduate level, some members of the faculty must be materials scientists doing research in materials science. Since it is an applied science, the priorities assigned to different research problems are dictated by the needs as perceived by the materials technologist and engineer. The basic science which is lacking in an area of interest to materials engineers in Canadian industry may not be the same as that identified by engineers in other countries, who are responding to a different industrial environment. The materials science needed by Canadian engineers may not get the attention it requires unless there is some support for materials science in Canada.

Materials science is interdisciplinary. Perhaps it should be described as multidisciplinary. Consequently, professors with special knowledge of different aspects of materials science may be found in different departments of a university. Usually, it has been thought necessary to develop a coherent programme at the graduate level by forming some sort of extra-departmental organization such as a Materials Science Centre. In only a few universities in North America has it been possible to establish a graduate programme in materials science as a major departmental programme and even where this has been achieved the active cooperation of professors in departments other than the materials department is essential to the success of the programme. At the other extreme, in some universities an extra-departmental organization for research has been established without there being an accompanying academic programme in materials science. The faculty involved in the research organization teach in their basic discipline and provide the basic science courses for materials engineers.

Materials Engineering deals with solving specific problems. These problems usually contain many uncontrollable variables. Economic, social, psychological and purely physical factors may all be important components. No uniquely correct solutions exist. The objective is to optimize the system or to provide a practical solution which is socially tolerable and economically viable. The materials engineer must utilize the best available materials science and his solution must be compatible with scientific understanding. In the past, the materials engineer usually was concerned with only one class of material. He was trained in the science and practice of a specific materials technology. The metallurgist who devoted his attention exclusively to problems associated with the rolling of steel saw no reason to be concerned with the extrusion of polymers, nor did he see any significant connection between the technology which was the basis of his concern and that of the polymer engineer. Although there are many interesting similarities between the fabrication methods used to form different classes of materials, even today the materials engineer in materials production industries sees little value in a general training which emphasizes these similarities. It is usually stated that all the time and effort available is needed to master an understanding of the technology of a single class of materials.

In the past, most materials engineers have been trained as metallurgists. Others have received their initial training in ceramics or polymer engineering. This situation continues to be satisfactory as far as the materials producing industries are concerned. However, in those industries in which the materials engineer is concerned with the use of materials, there is a growing realization that the materials engineer needs to have knowledge in some depth of a wide variety of materials. Whereas twenty years ago virtually all of the materials problems relating to automobile manufacture were concerned with metal, now they also involve a variety of non-metallic materials. While no engineer can be an expert in the technologies of all materials, an appreciation of the behavior of engineering materials systems has become an essential part of his work. To meet Canada's future needs, materials engineers trained to the PhD level will have to have a knowledge in depth of one class of materials and a working understanding of a range of related engineering materials.

Recognizing the need for a comprehensive materials engineering programme, both at the undergraduate and graduate level, in many of the universities in North America, existing groups of faculty members in ceramics and in metallurgy have joined for the purpose of developing a unified programme in materials engineering. At some universities, polymer engineers have been added to the department.

The interface between materials engineering and other forms of engineering is diffuse. So many problems in mechanical engineering, for example, are dependent upon the capabilities and limitations of existing materials that often mechanical engineers find themselves devoting almost all their attention to the materials. Thus, they become knowledgeable about the properties of a small class of materials. However, they usually remain mechanical engineers with a special knowledge of a limited range of materials and they should not be confused with materials engineers. Conversely, the materials engineer working on a materials problem in a specific mechanical engineering environment may become familiar with an area of mechanics or fluid dynamics or some other part of mechanical engineering. Effective interaction of this kind is essential if he is to be a successful materials engineer. However, knowledge of a part of mechanical engineering does not make him a mechanical engineer. Clearly, it is important that we note the numerous materials-related activities in the other areas of engineering. The training and education of engineers working in these areas were not a part of our study but we will comment upon these topics indirectly in this report.

The summary of institutional aims contained in the Report on Doctoral Studies in Metallurgical Engineering and Materials in the Province of Ontario, Appendix 2.1, is a statement of the present situation although it is intended to be a five-year projection. As a result, the graduate programmes decribed in the report as research programmes are categorized under the three principal subdisciplines: extractive (chemical) metallurgy, physical metallurgy, and materials research. This description reflects the historical development of the departments, but the fact that department heads, in their statement of future plans, decided to use these particular subheadings suggests that they have no intention of moving towards a materials engineering programme of the kind described above. Component pieces of materials science can be found under the headings 'physical metallurgy' and 'materials research'. At McMaster the range of such component subjects and their inter-relationship is such that a reasonable programme in materials science exists. There is a partial programme in materials science at Toronto and no evidence of such programmes anywhere else.

The number of students and post-doctoral fellows in each of the subject areas, now classified according to the material, are summarized in Appendix 2.2. The number of MSc and PhD students in extractive (chemical) metallurgy is as great as that in all of the other materials engineering and materials science areas put together. This, of course, reflects the great importance of extractive metallurgy in the Canadian economy. Amongst the materials engineering subjects, the importance attached to metals is overwhelming. The existence of a significant effort in electronic materials and composites shows an encouraging response to the needs of developing Canadian industries based upon sophisticated science. Out of 91 graduate students the presence of only 5 involved with ceramics and glasses suggests surprising neglect of this rapidly developing and important materials area. However, the most striking fact to emerge from these returns is the complete absence of any effort in polymers. While we realize that this does not mean that no work on polymers will be undertaken in the next five years in Ontario universities, it does mean that all the work in this area will be carried out in departments of chemical engineering, chemistry, mechanical engineering or elsewhere and not in materials departments. The importance of polymeric materials as a constituent major area of materials engineering need hardly be emphasized. The particular contribution that can best be made by a materials department is in the elucidation and control of structure-property relationships.

We recommend that, relating to doctoral programmes in the Province of Ontario,

1. The substantial effort in extractive (chemical) metallurgy already existing in some universities in Ontario be further strengthened.

2. At least one of the existing programmes in materials science be strengthened to ensure that there will remain in Ontario a materials science activity of international stature.

3a. Wherever viable programmes in metallurgical, ceramic or polymer engineering exist they be combined and augmented to develop strong programmes in materials engineering.

3b. The proportion of the effort in materials engineering devoted to ceramics and glasses by increased.

3c. At least one materials engineering department be established or expanded in an Ontario university to develop a strong programme in polymeric materials integrated with a general materials engineering programme.

THE SUPPLY OF AND THE DEMAND FOR MANPOWER

In Table 9-5 of Ring of Iron, it is shown that, of persons holding doctoral degrees in 1967, 35.7% were employed in research, 26.3% in teaching, and 20.0% in management. It was assumed that the major demand for PhDs in engineering would be in research and teaching. Using a model which assumed a small and gradual expansion in the undergraduate enrolment, a constant ratio between the number of academic staff and undergraduate and graduate students, and an attrition rate of 3.4% for the Province as a whole, it was estimated that, on the average, the demand for additional faculty in engineering would be about 62 per year throughout the decade 1970-1980. A further assumption is made that "over the present decade research activities probably will remain relatively static, and therefore the demand for research engineers will consist almost entirely of the need for replenishment to make up for yearly attrition". Then, making further allowance for the emigration of PhDs out of the Province, it was estimated that the total number of new PhDs required per year will be 125. No attempt was made to estimate the number of PhDs required in individual engineering disciplines. A more detailed analysis of manpower requirements, entitled Supply and Demand for Engineering Doctorates in Canada, was published in 1973 by the Canadian Engineering Manpower Council (CEMC, 1973). A model similar to that in the 1970 Lapp report was used to estimate the demand from universities and a survey was made to estimate the industrial demand. The 1973 CEMC report concluded that "one cannot readily dismiss the conclusion that there will be an oversupply of engineering PhDs in the decade ahead". On certain assumptions, "the difference amounts to 42 PhDs in 1974, 23 in 1975 and 87 in 1978. Again, these differences are not causes for alarm but they do suggest that some curtailment of engineering doctoral enrolments is justified if the graduates are to be utilized to the maximum possible extent of their training". Throughout both reports there is the implied concern for the usefulness of PhDs in industry.

The CEMC report of July 1973 presents a very different picture from that in its predecessor, the Ring of Iron, concerning the demand for engineering PhDs in the universities. On page 125 it is concluded that "reductions rather than additions to staff" will be required up to 1980-81 although the error of projection could be as large as the projected decrease amounting to 160 or 10% in 10 years. This is notably different from the conclusion in the Ring of Iron, page 54, "Therefore the demand for teachers educated as engineers in Ontario universities was assumed to be 60 PhDs a year over the next decade". Neither projection carried any degree of credibility since major changes in the pattern of education with a marked rise in the Colleges of Applied Arts and Technology are already taking place.

In general, it appears that the 1973 CEMC report has been compiled with a strong bias against increasing the number of engineering doctorates being produced whereas the evidence given below suggests that the most important change taking place is an increase in the demand for doctorates in chemical, metallurgical and mechanical engineers, and materials applied science.

There are several difficulties in making a fair assessment from past statistics. PhD degrees in metallurgical engineering have been offered only in recent years by Canadian universities. Those now practicing in this field very often have received their doctorates in chemical, mechanical or civil engineering. Moreover, those who have taken an engineering degree at the bachelor's or master's level have in many cases taken their materials science degree from a science department. It follows that there are practicing engineers, qualified in metallurgy and materials science, whose PhD was not granted by an engineering department. Also, those who received their degrees many years ago are likely to have earned it in mechanical, civil or chemical engineering. This same practice continues in one major university in Ontario, namely Waterloo, where no doctoral degree in metallurgical engineering, either extractive or physical, is given. Those qualified in these metallurgical disciplines are therefore apt to be classed as mechanical or chemical engineers.

Information given for Atomic Energy of Canada Limited (AECL) in Tables 1 and 2 of Appendix 3 may be used as a starting point for assessing changes in demand. Perhaps the most striking feature is that, in the last five years, the number of engineering PhDs has risen to match those in the physical sciences. Moreover, mechanical, chemical and metallurgical engineering are the fields carrying most of the increase. From Table 1, Appendix 3, it would appear that the total stock of engineering PhDs is 90 and that may be compared with the figure of 52 quoted in Footnote 3 to Table 46 of the 1973 CEMC report. Even 90 is deceptively low because, from the next two columns, it will be seen that there are 20 more with PhDs in the field of metallurgy and materials science. Combining metallurgy and materials science with engineering would make the total 110, to be compared with 144 in the physical sciences, and for the last five years the number would be 62 compared with only 42 in the physical sciences.

Table 2 illustrates another point that it is more customary for PhDs to join the staff of AECL after spending one or two years on a post-doctoral fellowship. The number of those with 1972 and 1973 degrees is therefore still significantly increasing. Looking at the numbers by year of appointment, it is also clear that more are still to be appointed in 1973. Returning to the CEMC report, Table 57, page 159, indicates a Federal Government demand of 30 3 in 1974, 35 5 in 1975, and 25 6 in 1978. Yet these figures are very close to those given in Table 46, excluding AECL. Since AECL's 1973 stock, just discussed, is 90 to 110, it would seem that an increase of 8 to 10 per year should be made to the figures in Table 57. It is difficult to escape the suspicion that the projected demand, in Table 57, in other sectors may also be low. Although the largest increase is shown in industry, it seems possible that this may not have taken into account other important changes in Ontario. Although AECL is largely concerned with nuclear power, the main increase in staff in that field does not lie in AECL but in Ontario Hydro. Moreover, Ontario Hydro has undertaken a major new activity in the production of heavy water, for which recruitment of competent operating chemical engineers is active and projected to increase. This is in addition to the major increases, forecast by Ontario Hydro, arising from the transition to thermal generating stations and their much greater capacity than the established hydro-electric stations. Other major industrial increases forecast in Ontario are in steel manufacture and petroleum refining. Both these may be expected to have demands for PhDs in chemical, metallurgical and mechanical engineering.

Another major objection may be raised against the CEMC report on pages 134-135 where it is suggested that the demand for doctorates will be negligible in the educational institutions other than universities. Even the statement concerning primary and secondary school teachers is somewhat misleading since, if taken in proportion to the population, the 62 teachers quoted represent 1.4% of the doctorates in the major field of university education.

In summary, we conclude that the estimate of the annual demand for PhD graduates in mining-metallurgy-materials science in the Canadian Engineering Manpower Council report of July 1973 is much too small. The demand for graduates of PhD programmes in materials engineering and materials science alone may well prove to be twice as large as the numbers given in Table 58 of the report. The demand for PhD graduates in extractive metallurgy may, on the other hand, increase more slowly. Even if all the students at present enrolled in PhD programmes in universities in Ontario took employment in Ontario on graduation the supply of materials engineers and materials scientists would fall far short of meeting this demand.

To the present, the number of PhDs graduating in materials disciplines from universities in Ontario who took employment in the Province has been a small fraction of the PhDs in these disciplines needed in the Province. There has been a large importation of PhDs from foreign countries, particularly the United Kingdom. We found, for example, that, of the faculty members recruited to the departments of metallurgy and materials science at McMaster University, the University of Toronto and Queen's University over the last ten years, only 7 out of 38 received their PhD degrees in Ontario. Similarly, for Atomic Energy of Canada Limited, the major employer in Ontario of PhDs in metallurgy and materials science, between 1968 and 1973, 14 persons with PhDs in materials science and engineering were hired. Only four of them received their PhDs in Ontario. Eight of the 14 received their doctorate either in the United Kingdom or some other foreign country. Many of senior positions in industrial research and development in Ontario industries are held by immigrants from the United Kingdom. In the past ten years there has been a substantial importation of PhDs from the United Kingdom into the metallurgical industries of Canada. There is little reason to believe that this rate of influx will decrease substantially. Employers of British origin appear to have a preference for graduates of British universities. The situation is the same in the universities, where a substantial proportion of the faculty members in the departments of metallurgy and materials science received their PhD training in the United Kingdom. In a few places we even heard the view expressed that to hire faculty members from the graduates of programmes in other Ontario universities would produce inbreeding of an undesirable kind! It is our view that the graduates of PhD programmes in British universities today do not have an educational experience that is superior to that available in the departments of metallurgy and materials science of universities in Ontario, nor do they have special knowledge or skills which cannot be found in Canada. Thus, the large scale importation of foreign PhDs can be justified only to the extent that the output of PhDs from Canadian universities falls short of the demand.

In the past, many PhD graduates of universities in Ontario have moved to other parts of Canada or to a foreign country, particularly the United States. From 1968 to 1972, there had been 45 PhDs in metallurgy and materials science awarded in the Province and there are 40 students enrolled in PhD courses in materials at the present time (Appendix 4). Of the graduates, 29 had remained in Canada, most of them in the Province of Ontario. In the CEMC 1973 report it is pointed out that Ontario has been providing 55 to 60% of the total domestic supply of engineering PhDs and this proportion is expected to increase over the next decade into the 70% range. The movement of PhDs from Ontario into other parts of Canada is expected to continue, but the emigration to the United States is not. Many Canadian students we talked to expressed a strong desire to work in Canada and preferably in Ontario. Recent changes in the immigration laws of the United States have made it extremely difficult for Canadian graduates to move across the border into lucrative employment. Although the migration to the United States is not likely to disappear, it will certainly diminish in the future. On balance, the proportion of graduates of PhD programmes in materials who stay in Ontario is not likely to change significantly over the next five years. Thus, the shortage in Ontario will be further aggravated by the expected migration of about a third of the graduates to other parts of Canada.

An assumption explicitly stated in the Ring of Iron, 1970 and implied in the CEMC 1973 report with which we take issue is that the PhD degree is of limited usefulness in an industrial situation. It is argued that because a master's degree is much more useful, resources and efforts should be concentrated on improving the quality of master's degrees and increasing the number of graduates from such programmes. The arguments are stated clearly in Ring of Iron, 1970. It is pointed out (Table 9-5) that close to 60% of the engineers with master's degrees are in management, design, and development. It is stated that with "Canada's move into the post-industrial era there should be an increasing flow of engineers into the service sector and this implies a demand for specialty skills to satisfy the wide variety of tasks executed by these 'knowledge' industries. In the future, more Canadian employers will be forced to insist on a master's degree for certain specialized skills." When viewed in a different way, however, the statistics in Table 9-5 of Ring of Iron, 1970 show that, with regard to positions in industrial research and management, the PhD in industry has an 85% chance of reaching these categories compared with a 58% chance for a person with a master's degree. It is our belief that, as Canadian industry becomes more sophisticated and has to rely upon more advanced technologies, it will have to learn how to fully utilize the talents and skills of PhD graduates, and the universities will have to learn how to develop PhD programmes which produce imaginative engineers capable of responding to these new opportunities. It is interesting that in Ring of Iron, 1970, attention is drawn to the importance of the specialized knowledge of master's graduates. Part of the existing problem seems to be that the PhD programmes in universities in Ontario rely heavily upon the thesis so that the graduates of these programmes tend to have a deep knowledge of only a small field. Industry evidently employs PhDs only when it needs this particular knowledge. This problem will be discussed further when we consider the quality of the educational experience.

Questions of supply and demand of PhD graduates in metallurgy and materials science are clouded by the intangible problems associated with students of non-Western origin, by which is usually meant Asian students. These students are probably best identified by the country in which they receive their first degree. The information is summarized in Appendix 3, Table 3. Data are given for both master's and PhD degree candidates because most of the students registered for a master's degree go on to the PhD. The number of students registered for the master's degree in all the departments in Ontario has varied little over the last five years, from 55 students in 1968-69 to 40 students in 1972-73. Moreover, the number of PhD students is about the same, being 55 in 1968-69 and 44 in 1972-73. The percentage who received their bachelor's degree from a Canadian university dropped from 49% in 1968-69 to 30% in 1971-72 for those registered for the master's degree, and from 50% in 1968-69 to 33% in 1971-72 for those registered for the PhD. Last academic year the percentage of master's candidates with first degrees from Canadian universities jumped abruptly from 30% to 48%. This probably reflected the increased difficulty which foreign students have experienced in obtaining support for their graduate work, and the success of aggressive campaigns by a few departments to recruit Canadian students. The percentage of Canadian first degrees amongst

PhD candidates continued to decline, reaching its lowest proportion (25%) towards the end of last year. Amongst the PhD students, the proportion with bachelor's degrees from Asian universities increased remarkably over the last five years, being 18% in 1968-69 and 32% in 1972-73.

In the last few years, most, though not all, of the Asian students have had landed immigrant status. They usually receive support through National Research Council fellowships after completion of their first year of study. Many of them are supported also during this first year from other sources. The dramatic decrease last year in the proportion of students with Asian degrees in the master's population will be reflected in the statistics for the PhD population in two to three years. It is recognized in the CEMC, 1973 report that graduates of Asian origin have difficulty in obtaining employment of a kind which utilizes their educational level in Canadian industry. In our talks with many of these Asian students we were left with no doubt that they all find extreme difficulty in obtaining suitable employment. From several people we heard stories of their making as many as a hundred applications for jobs without receiving a single invitation to an interview. The conclusion that the research and development sectors of Canadian industry have a strong prejudice against employing Canadian PhD graduates of Asian origin is inescapable. Even in the last year or two, when the job situation has been difficult in all fields of engineering, Canadian industry, unable to fill its vacancies with Canadian graduates of Canadian origin, has preferred to import graduates from British or Australian universities rather than employ Canadians of Asian origin. Setting aside the social and moral implications of the situation, as a practical matter it seems unwise for departments of metallurgy and materials science in Ontario to continue to recruit a large proportion of their PhD student population from Asian universities. The very recent increase in the proportion of Canadian students in master's programmes (Appendix 4, Form 7) suggests that the efforts of some departments to alter the ratio may be meeting with success.

Doubts are certainly current concerning the value of a PhD degree in obtaining suitable employment. Writers in the media derive pleasure from discovering that a PhD had been obliged to take a job as a taxi-driver and the rumour readily spreads that this is typical. On the other hand, the records of employment of those earning PhDs in materials engineering in the last 5 years from Ontario universities showed that of a total of 45 no more than one was unemployed at any time and none was unemployed for long. By careful enquiry from university staff and graduate students at the universities visited we gained the impression that only those specializing in extractive metallurgy, especially in iron and steel, were finding no employment offers from industry in Canada. Even these had offers from the U.S.A. A special meeting was therefore arranged through the generosity of the Canadian Research Management Association to hear the views of industrial employers of materials scientists and engineers. They confirmed that the bad stories in the press gave a false impression and tended to promote a siutation playing down the value of the PhD both to student and employer. In general there are openings for qualified materials engineers and scientists, especially for those of broad general ability who can exercise leadership in research and in management. The position in industry may change rapidly, going from surplus to shortage in two years or less. Moreover, at any one time industrial opportunities are uneven. There was substantial confirmation of a more general appreciation of the highly qualified PhD in certain industrial sectors including non-ferrous metallurgy, nuclear engineering and science oriented sectors. It was admitted that in ferrous extractive metallurgy there was not in Canada a high appreciation, such as in Germany, Japan and other progressive competing countries. The general impression was that industry expected to be increasing their demand with only temporary and localized setbacks of perhaps two or three years duration in any one company or sector.

We recommend that:

1. The figures for anticipated demand in 1974-75 for PhDs in Ontario in 'mining, metallurgy and materials' be at least double those given in Table 58 of the report of the Canadian Engineering Manpower Council, July 1973, and the targets for the total PhD student population in these disciplines be adjusted accordingly. Most of the necessary substantial increase in the output of PhDs should be from departments with comprehensive programmes in materials engineering or materials science or both.

2. Efforts to recruit a larger proportion of the PhD students from the graduates of Canadian undergraduate programmes should be continued and intensified. The stipends paid to Canadian graduate students are inadequate to attract a sufficient number and should be increased substantially.

The supply of PhD graduates is, of course, limited by the intake of the various PhD programmes in the department of metallurgy and materials science. In general, we found that there were enough funds to support the present number of PhD students and, in some universities, there was a substantial surplus of funds for this purpose. The surprisingly large post-doctoral populations in the departments in Ontario revealed by the data in the table in Appendix 2.2 is in part a reflection of these surplus funds. More research, much of it of excellent quality, is being carried out in Ontario universities than is needed to support the PhD programmes. Much of this research is being carried out by post-doctoral people and faculty. Clearly, it would be possible to fund a substantial increase in the population of PhD students by a proportionate decrease in the number of post-doctoral fellows. Whether this could be done without sacrificing some of the quality of the research output is questionable.

It is clear that, in most universities in Ontario, the number of students applying for admission and being accepted into PhD programmes in materials, or to master's programmes preceding the PhD, is the factor primarily responsible for restricting the supply of PhDs to industry. It is difficult to form an opinion about the admission standards applied by individual departments because such a wide variety of crieteria are involved. However, we formed the general impression, admittedly much colored by one or two isolated examples relating to situations with which we have had some experience, that the standards are not unusually high.

In the past, most departments have recruited their graduate students from undergraduate departments of metallurgy and materials science. There were 221 graduate students registered in metallurgy in Canadian universities in 1972-73. Approximately 70 new graduate students are required to cover attrition and graduation this summer if graduate enrolment is to be maintained. However, only 131 bachelor's degrees in metallurgy are being awarded in 1973. Usually, 15% of the graduating class enters graduate school so that only about 20 graduate students will be available from this source. Even if a further 20 students are recruited from other disciplines a net shortfall of 30 students remains. This has traditionally been met by accepting foreign students. One can therefore conclude that Canada does not produce enough metallurgical bachelor's graduates to come near meeting the requirements of its graduate schools. This is the crux of the problem in metallurgy and materials science. There are several directions in which a solution could be sought. The proportion of the graduating class entering graduate school could be increased. This is a problem largely associated with the image that graduate work has in the minds of undergraduates and the prospect that they see for employment after they have gained a PhD. It was clear from our discussions with students that the general impression they had about job opportunities for PhD graduates was very different from that stated by faculty members or described by the press release from the Canadian Association of Graduate Schools, Appendix 5. The general impression is that jobs for PhDs are very hard to find and those that are available could just as well be carried out by persons with master's or bachelor's degrees. These impressions are reinforced when they see substantial numbers of students of Asian origin so obviously frustrated in their attempts to find employment. Clearly this situation will improve only when the general climate for the employment of PhDs improves.

Another approach is to increase the intake of students from undergraduate departments other than those concerned primarily with metallurgy or materials science. It is common for many departments of materials science in the United States to obtain a substantial proportion of their graduate students from undergraduate programmes in mechanical, electrical or chemical engineering or in physics, chemistry or geology. The graduate courses are designed, both in quality and level, to provide a complete educational experience for these students. In Britain it is very unusual for a student to change from one area to another on entering graduate school. Few Canadian departments offer the spectrum of interesting courses necessary to attract students into materials engineering or materials science. This situation will be discussed in more detail in the next section.

We recommend that graduate programmes available to students entering materials science and materials engineering from other undergraduate programmes should be designed to make the transition as meaningful as possible, and also to attract students into the subject area. Graduate programmes should be examined with this objective in mind.

THE QUALITY OF THE EDUCATIONAL EXPERIENCE

In the Western tradition the PhD degree is a mark of successful completion of a course of initiation in research. Of course, this implies a lot more than the student's receiving instruction in some particular techniques or gaining an expert knowledge of a very narrow topic. We were asked to appraise the quality of the various programmes in metallurgy and materials science in Ontario. To do this we must first set out our views on the purposes of such PhD programmes and the nature of the essential ingredients of such a programme. We believe that the purpose is to provide the student with a variety of opportunities to develop his talent for science and technology and his interest in materials. In the course of his PhD work he should provide himself with a strong basis in the physics and chemistry of solids and the interwoven discipline of materials science and a broad interest in materials in general. In addition he should learn how to plan and carry out a research project and how to define a problem and study it in depth. He should learn how to assemble his arguments and conclusions, present them to his critics and peers, and benefit from their constructive criticism. It is firmly held by advocates of the British system that all these experiences can be obtained by the student's receiving guidance and encouragement from his thesis supervisor during the course of two or more years devoted almost exclusively to a research topic. In the American system it is considered that it is necessary to provide a range of formal courses from which the student can select related courses which fit his particular needs. In addition, the student carries out research on a topic very similar to that selected under the British system and he receives the same type of guidance and encouragement as his British counterpart.

We, of course, agree that the educational experience most likely to have lasting importance to a student is his interaction with individual members of the faculty. At the graduate level the student teaches himself and should not require the discipline of formal courses taught in the manner to which undergraduates have become accustomed. However, not believe that, except for the most unusual student, meaningful personal contact can be made through chance meetings at coffee or in the corridor. It is possible for a student to appreciate fully the intellectual vigour of a professor only by the student's participating in a course in which the professor sets out logically and systematically his analyses of, and thoughts on, an advanced topic and where the student has had an opportunity to interact with the professor in a small class. All students learn a lot from their association with their thesis supervisor, but if the student's experience is limited to one faculty member his total experience, almost certainly, will be less than adequate. Of course, what a student derives from any arrangement of graduate studies depends to a large extent upon the student himself. The well-motivated, highly intelligent student with good work habits will benefit from almost any situation. This explains why no obvious correlation exists between the performances and achievements of PhD graduates and the system in whcy they were educated. In any national system the best students tend to seek admission to the best schools and, on balance, these are the students who achieve the most after they have graduated. In our view a graduate programme should be judged by the quality and range of opportunities it offers to the student, not by the achievements of occasional outstanding individuals who may have gone through the process in the past.

It is usual in Canadian graduate schools to adopt a middle course between the British and American system. In most of the programmes we examined in Ontario there was considerable emphasis on the thesis and the importance of the thesis supervisor, but there was also a substantial course requirement which varied between three two-term courses and eight half courses. Although not quite so large as the course load usually required of graduate students in the United States, it is still a large load. It should be adequate to provide the range of experience which the best students are seeking, provided that the courses have a suitable content and are well taught. We detected, however, a tendency in some universities in Ontario to regard the purpose of graduate courses to be simply to fill some gap which is imagined to exist in the undergraduate programme. Many such courses were lectures on experimental techniques. This tendency to downgrade graduate courses until they are little more than supplements to laboratory experiments is particularly noticeable amongst faculty members who received their education in Britain. We will comment upon the range and quality of graduate programmes when we discuss the programmes in the individual universities.

All categories of materials programmes require a solid basis in the physical sciences and, consequently it is important that the student should have contact with physicists and chemists and applied mathematicians. The range of experience needed by students in the three types of materials programmes with which we are here concerned are different. The student in extractive (chemical) metallurgy, would benefit by exposure to faculty in mineral engineering and chemical engineering, as well as interaction with faculty and students in materials engineering within his own department. In some universities a substantial part of the extractive metallurgy curriculum is contained within the chemical engineering department. It is also a subject which is, in part, suitable for treatment by econometric models and other operational research techniques and it is probably desirable to encourage students to have some experience of these industrial engineering methods while they are still in the university environment.

Students who intend to become materials engineers need to have access to courses which develop, in as sophisticated a way as possible, the particular materials technology in which they intend to specialize. In addition, they will want to broaden their knowledge of materials in general by having available courses covering a range of technologies and the materials sciences on which they are based. It is important also that such students should be intimately connected with the work of other engineering departments in the university and of engineers in industry or government service. Effective interaction with industry is particularly important during the years of graduate study and very difficult to achieve.

Materials science is made up of a range of disciplines. A materials science programme can be put together by an association of faculty expert in these component disciplines, from different departments, or the programme can be interdisciplinary within a single department of materials science. Only a few of the largest departments in the United States have a staff with a suitable variety of backgrounds to have been able to develop a materials science programme largely within the department. In most places the programme in materials science is an association of faculty members from a number of departments, although in many cases there is substantial concentration within a department which may contain the words 'materials science' in its title.

In many universities in the United States interdisciplinary materials science activities have developed around central research organizations, known in the original programme as Interdisciplinary Laboratories for Materials Research. Some twelve years ago a dozen of these centres were established by the Advanced Research Projects Agency of the Department of Defense. These, and a few other centres established by other agencies, vary considerably in size and in style. They are all 'horizontal structures', meaning that they are an association of faculty members from several departments of the university who come together to develop an interdisciplinary activity in materials. Three similar centres, although on a much smaller scale, were established a few years ago in Canada. The National Research Council negotiated Development Grants to the universities of McMaster, Toronto and British Columbia. We will comment about the effectiveness of the research centres at Toronto and McMaster insofar as they have played a role in the development of materials science programmes at those universities. Other research centres related to materials work, but not essential to materials science, have been established at other universities in Ontario. A few of these have had some impact on the materials programmes, as will be indicated later.

Before discussing the programmes at individual universities, we must address the general question of the critical size of a department if it is to be effective. This critical size depends, of course, upon the nature of the department and the objectives of its programmes. If the British view is adopted that the total graduate experience is centred around the thesis, then an effective programme requires only one good faculty member. Some well-known departments of metallurgy in Britain have, in the past, contained only two or three professors. If, however, the American view is adopted then the departments need to be sufficiently large to provide a proper range of courses from which the student can select his programme. Obviously all the courses need not be offered by a single department. In our view, it is desirable that the student should be taught by faculty members from the basic science departments as well as by faculty members from the engineering school. Whatever arrangement is adopted, if a programme in extractive (chemical) metallurgy or materials engineering is to have cohesion, at least a core of subjects must be offered within the department of materials in the engineering school. The critical size of this core depends a great deal upon the strengths in related disciplines which exist within the university and the extent to which the departmental programme utilizes suitable courses outside the department. In certain circumstances a departmental programme in extractive (chemical) metallurgy requires only three or four faculty members to cover the core subjects in pyrometallurgy, electrometallurgy, high temperature chemistry and oxidation and corrosion. It is unusual, however, for materials engineering programmes to be able to draw on many courses on specific materials technologies offered by other departments. Here the problem of coverage often becomes acute. It requires a substantial number of faculty members to be able to provide in-depth graduate courses covering the processing, properties, and engineering utilization of metals, ceramics, polymers, and electronic materials. Because historically most materials engineering departments have developed from metallurgy departments even those departments with a large number of faculty members often put an excessive emphasis on metals. If a materials science programme is made up of courses drawn from a number of different departments, then the number of faculty members in the materials department need only be two or three to provide some focus for the programme. There are a number of viable material science programmes which have developed in this way. However, in other universities the interest shown by faculty members in chemistry, physics, geology, electrical engineering, etc. has been insufficient to provide a basis for developing a programme in materials science, and the initiative has had to be taken by the materials department in the engineering school. In these circumstances the department needs faculty members in the different component disciplines of materials science. In a few universities in the United States interdisciplinary departmental groups with more than a dozen faculty members have been developed for this purpose.

During the course of our discussions with members of the faculties of departments of metallurgy and materials science in Ontario, we occasionally encountered the argument that in order to attract good faculty members to teach the undergraduate programmes and to keep them happy after they have been recruited, it is necessary for there to be opportunities for research and the research should be carried out by graduate students; therefore there has to be a PhD programme, however small the number of faculty members and students involved in it. We do not fully accept this argument. If a member of the faculty of an undergraduate department wishes to continue his research this can be done effectively using research assistants and post-doctoral fellows. It must be admitted, however, that most professors with a strong interest in research are unlikely to be content to work in a predominantly undergraduate environment.

ASSESSMENT OF THE PROGRAMMES AT INDIVIDUAL UNIVERSITIES

The programmes at the different universities are discussed in the order in which most of the consultants happened to visit the campuses.

McMaster University

The department concerned with materials at McMaster University is called the Department of Metallurgy and Materials Science. Candidates are accepted for graduate work leading to the MSc degree in Materials Science, to the MSc degree in Metallurgy and to the MEng in Metallurgical Engineering or to the PhD degree in Metallurgy or Materials Science.

At the undergraduate level the programmes are in the Metallurgical and Ceramics Engineering. In addition, there are undergraduate programmes in materials science (in the Science Faculty) and in engineering physics.

Data relating to the materials programmes at McMaster University, collected by ACAP, are summarized as follows. The staff of the department consists of seven full professors, two associate professors and one assistant professor. Four of the faculty members described their field of specialization as extractive metallurgy (2.4 FTE), six as physical metallurgy (3.6 FTE), three as engineering materials (1.1 FTE), and seven as materials science (2.9 FTE). However, at the PhD level only two programmes are offered, one in metallurgy and the other in materials science. Currently there are 36 students enrolled in the graduate programmes, a number which has varied little over the last few years. Of the sixteen in metallurgy, seven are doctoral candidates in extractive metallurgy, six are stated to be in physical metallurgy and three in engineering materials although neither of these fields is listed as an area of graduate study in the catalogue. Of the seven PhD candidates in materials science only one is an engineer. After talking with some of the students and staff and examining the details of the programme in materials science we came to the conclusion that all the doctoral candidates listed under physical metallurgy, engineering materials and materials science could be included in the category which we have described earlier in this report as materials science. By the nature of the courses selected and the research topics on which the students are engaged, some of these materials science programmes have more of an engineering flavour than others. Of the 36 graduate students enrolled at the present time, 13 have first degrees from an Asian university.

The engineering school at McMaster University has not yet reached its undergraduate enrolment 'ceiling'. There are at present only 600 undergraduates in engineering. Of the freshman class of under 200, about 100 of the students are uncommitted when they enter the university. Of these an average of 8 students per year elect to take metallurgy. Five students in the Science Faculty elect materials science each year, and about a dozen other students take some materials science courses through the Engineering Physics programmes. Only a small fraction of this small undergraduate population do graduate work after they have their bachelor's degree and only a fraction of these graduates elect to do their graduate work at McMaster. Thus the undergraduate programme is not a very productive source of candidates for admission to the graduate programmes. We recommend that the Department be given the opportunity to introduce materials science to all engineers before they have selected their undergraduate options.

At McMaster University research on materials is organized by a multidisciplinary Institute of Materials Research which embraces eight departments; the Department of Metallurgy and Materials Science, together with Chemistry, Physics, Geology, and four engineering departments - Chemical, Civil, Electrical and Engineering Physics. The Institute also includes associates from industry and government. At the present time these are represented by members from Westinghouse (Canada) Limited, Welwyn (Canada) Limited, and Atomic Energy of Canada Limited. A total of 41 faculty members in the university are active members of the Institute for Materials Research. Most of them are housed in large modern buildings which are adjacent to each other and so facilitate intermingling of the staff, graduate students and technical assistants. The Institute was founded and has received continuing support from an NRC Negotiated Development Grant. A substantial proportion of these and other resources have been devoted to building up experimental facilities which are used in common by groups of faculty members of the Institute. These facilities are excellent and equal to similar facilities in other parts of the world. The research covers a wide range of topics in materials science and the productivity of the members, as indicated by the output of publications, is high. There appears to be active interdisciplinary cooperation which is fostered by seminars held within the Institute and by the impressive visiting professors programme. Another area in which materials scientists play a significant role is in the newly established metal-working group within the Faculty of Engineering. This activity is also the result of a Negotiated Development Grant, the annual contributions from which over five years will total $800,000. All the members of the department of Metallurgy and Materials Science are members of the Institute for Materials Research. To date, only two or three of them participate in the metal-working research programmes but it is expected that this participation will increase in the near future. It is remarkable that all ten members of the department receive personal operating grants from NRC, or DRB. In 1972/73 these grants totaled $183,350, averaging $21,407 per full professor and $12,000 per assistant professor.

The graduate programme in materials science is administered by the Department of Metallurgy and Materials Science. In addition to the faculty members of the Department, there are 13 professors from other departments associated with the programme. They are described as 'associate members'. They are drawn from the departments of Chemical Engineering, Physics, Geology, Chemistry, Electrical Engineering, and Engineering Physics. Thus the faculty members teaching in the programme represent a wide range of disciplines appropriate to materials science and the courses that are available to the students cover a complete spectrum. Visiting professors brought to the university through the Materials Research Institute have contributed interesting supplements to the courses offered by regular faculty members. As with most graduate programmes at McMaster, there is a strong emphasis on the scientific basis of the subject and a good deal of importance is attached to the course work taken both inside and outside the department. In the materials science programme there is a minimum requirement of four courses, although most students take more than this number. We found that many graduate students take advantage of the courses offered by faculty members in other departments to supplement their departmental courses.

The admission standards applied to candidates seeking entry to the materials science programme are as high as those imposed by any of the other schools of materials science in the United States or the United Kingdom, but not so high as to account for the rather small enrolment of graduate students in the programme. Between February of 1972 and June of 1973, 117 applications were received, only eight of them from Canadian students. Twenty-seven offers, seven of them to Canadians were made, and fourteen of these offers were accepted. One or two of the Canadian applicants came to McMaster. This year an aggressive campaign has been launched to try to attract Canadian students from disciplines other than metallurgy and materials science. It is too early to judge the success of this effort, but we are hopeful that there will be a marked improvement next year.

The graduate programme in materials science at McMaster is the best programme of its kind in Ontario and probably in Canada. It provides excellent opportunities for qualified graduate students to study and carry out research over the whole spectrum of materials science in a scholarly atmosphere with first-rate professors and with appropriate interaction with other engineering disciplines and industry.

It is the only materials science programme in Canada which covers adequately the basic science related to all classes of materials, including polymers. The polymer work is done by faculty members of the Departments of Chemistry and Chemical Engineering. This part of the programme could be improved by the addition of a staff member to the Department of Metallurgy and Materials Science with a special interest in polymer structure-property relationships who could also provide liaison with these other departments.

The graduate population in the programme in materials science at McMaster University could be doubled without developing the need for any significant increase in the resources allocated to the programme. The limit to the size of the population is set only by the number of qualified students they can attract into the programme each year. Only in the last year or two has there been a concerted effort to attract students graduating from physics, chemistry or geology undergraduate programmes in other Canadian universities. The course requirements should be re-examined to ensure that no unnecessary 'professional' requirements are imposed on scientists entering the course and that the programme is presented in as attractive a way as possible to the science graduates. We predict that a sustained campaign along these lines will produce a sizeable graduate population in materials science at McMaster within the next five years.

We recommend that the preeminent position in Canada of the materials science programme at McMaster University be recognized. The programme should be expanded and the efforts of the faculty members to recruit good students from undergraduate programmes in physics and chemistry should be supported energetically.

The doctoral programme in extractive metallurgy is not as strong as the programme in materials science. The research carried out by the small number of faculty members in the programme is of good quality and very suitable for thesis work for the PhD degree. However, the range of the programme is inadequate and no interdepartmental administrative arrangement which would facilitate broadening of the programme has emerged. For example, there is no attempt to incorporate courses in heat and mass transfer offered in the Chemical Engineering Department into the programme. A few years ago the extractive metallurgy group established strong working relationships with the large local steel companies, Stelco, Dofasco and Atlas Steels. These interactions are continuing. Moreover, interesting cooperation has developed between the extractive metallurgists at McMaster and those at Toronto, whereby they have jointly sought the help of the Department of Industrial Systems Analysis at Toronto, to develop courses in economic systems analysis for extractive metallurgists. These joint courses appear to have been very successful and there is every indication that this type of interaction could and should be developed further.

It was argued by some faculty members at McMaster that the small scale of the programme in extractive metallurgy was justified because the work they do is entirely 'scientific'. They argue that if they want to scale up their experiments they could use equipment and facilities at one of the steel companies. We urged them to develop these interactions without delay and to produce a better balance between the scientific and engineering contents of their programme.

It is tempting to suggest that the small number of faculty members specializing in extractive metallurgy at McMaster University be moved to Toronto to supplement the already substantial effort in this area at that university. However, it is recognized that such a move would be unacceptable to many people. There is also the fact that the programme at McMaster is largely concentrated in steelmaking, which is appropriate when one considers the neighbouring industry, whereas that at Toronto is more heavily weighted towards non-ferrous extraction.

We, therefore, recommend that the programme in Extractive Metallurgy at McMaster University be strengthened by adding one faculty member and by increasing the participation of appropriate faculty members from the Department of Chemical Engineering. Collaboration with the complementary extractive group at the University of Toronto should be continued and extended.

University of Toronto

There are 14 faculty members in the Department of Metallurgy and Materials Science, five of them (4.0 FTE) working principally in extractive metallurgy. The others are described as being either in materials research or physical metallurgy or both (Appendix 7). This year there are 12 candidates for the master's degree and 8 doctoral candidates in extractive metallurgy, compared with five master's and five doctoral candidates in materials research. In addition, there are six master's and three doctoral candidates in physical metallurgy. It is rather surprising that although the words 'Materials Science' appear in the title of the department, they do not appear in the descriptions of the doctoral programmes. There is, however, a Materials Research Centre which, like the Materials Research Institute at McMaster, was developed from an NRC Development Grant. The Materials Research Centre at Toronto has members from the departments of Chemical Engineering and Applied Chemistry, Electrical Engineering, Civil Engineering, and Physics, in addition to six members of the Department of Metallurgy and Materials Science. No central experimental facilities comparable to those at McMaster have been developed, although equipment acquired by individuals and small groups of faculty members is standard and adequate. The Centre runs a useful seminar series, with internal and external speakers, which is well supported. Eight of the faculty of the Department receive NRC, DRB or MRC operating grants totalling $149,800 and averaging $12,483 per member of the Department.

The Department at Toronto has for many years had an international reputation for its graduate work in extractive metallurgy. Under the present department chairman this tradition is being maintained admirably. The range of research, the quality of the individual programmes and the general level of activity of research in extractive metallurgy are all excellent. There is good interaction with industry and support from the steel companies and others. Doctoral candidates are required to take 4 courses, 2 inside and 2 outside the department and there are some very attractive courses in extractive metallurgy from which the students can choose. However, the range of courses is surprisingly limited. More attention to courses in mass transport, hydrometallurgy and the economic aspects of extractive metallurgy is desirable. Perhaps new courses in these areas could be developed in cooperation with McMaster. There seems to be little difficulty in attracting good students into extractive metallurgy programmes and there appear to be employment opportunities for the graduates of the programme.

We recommend that the outstanding programme in extractive metallurgy at Toronto be recognized and used as a base from which to develop a larger and broader programme in mineral engineering and extractive metallurgy.

Some years ago Professor Bruce Chalmers established a school of physical metallurgy (or metal physics) at Toronto, specializing in research on the solidification of metals and alloys. Graduates of this programme now hold important positions in a number of universities in Canada and elsewhere in the world. It is difficult to know how to classify that part of the programme which remains in the Department today. It is not a materials science programme, although it has some of the components of such a programme. Nor does it cover the range of materials expected in a materials engineering programme, although there are some excellent courses in metallurgy and ceramic science. There is virtually no instruction in either the science or technology of polymers.

The individual faculty members in physical metallurgy and materials research at Toronto are excellent. Together they would constitute important parts of a programme in materials engineering. With the support of faculty members in other engineering departments, they could develop a first-rate materials engineering programme, although specialists in polymer engineering and electrical and optical properties of materials would need to be added. Similar support in materials science at Toronto is surprisingly weak. Although it is probably adequate to support an expanded materials engineering programme it is probably inadequate, at the present time, to provide the base from which a successful graduate programme in materials science could be developed. The Materials Research Centre should be greatly strengthened organizationally and by the addition of major, communally-operated experimental facilities.

We recommend that a full-scale graduate programme in materials engineering be developed at the University of Toronto by the addition of faculty members in appropriate specializations to the Department of Metallurgy and Materials Science (which should change its name). Cooperation with faculty members in other engineering and science departments who have an interest in the applications of materials should be developed and expanded.

/ Queen's University

The Department, described as the Department of Metallurgical Engineering, is made up of eight professors, four of them full professors, three associate and one assistant professor. The fields of research are described as physical and mechanical metallurgy, extractive metallurgy and materials science. When asked to declare their field of specialization all the staff selected 'metallurgy'. The individual faculty members are well qualified. A few have had some, and the chairman a great deal of, industrial experience and relations with local industry are good. A number of students complete their thesis work or do projects in local industrial laboratories. Ottawa is only two hours away by road and there is some interaction with the Mines Branch and NRC. The financial support from industry is meagre but there is an encouraging new development in the interaction with Chalk River. Five of the staff (2 full, 2 associate, and 1 assistant professor) receive NRC or similar grants totalling $51,500, averaging $10,300 per grant, and $6,438 per faculty member in the Department. The five members receiving grants are the only ones actively engaged in research. Three are productive, judged by the publication of papers in refereed journals. The other two have a small output of papers although they appear to be serious and dedicated researchers.

A Materials Research Centre, in which faculty members from Physics, Chemistry, Geology, Metallurgy and other departments collaborated, was established five or six years ago. It was disbanded last year. We could detect no enthusiasm on the part of the faculty members to revive it or a similar interdisciplinary organization. Two years ago faculty members in mineral engineering were split off from metallurgical engineering and added to the Department of Mining Engineering. This greatly strengthened Mining but weakened Metallurgy. It is claimed that there is still interaction between the two departments but these interactions are not strong at the present time. The Department of Metallurgical Engineering is housed in a good building and is well equipped for undergraduate and graduate teaching at the master's level. Specialized equipment needed for individual PhD research projects is adequate and in some cases good. Faculty and students share some basic equipment such as electron microscopes, but the group is too small to warrant the upkeep of central facilities. Some arrangements for sharing equipment with other departments of the university exist.

A master's programme in Metallurgy was established at Queen's in the 1920s, but the PhD programme is of recent origin. The first students were registered in 1964-65. The programme has a turnout of 8 graduates to date (plus 2 in mineral engineering). The total number of graduate students in the department reached a maximum of 23 in 1967-68, and has fallen to 11 at the present time. These students are about equally divided between extractive and physical metallurgy. There is no indication that any of the students want to pursue a programme in materials science. Of the 11 students currently enrolled, 6 are doctoral candidates, one of whom is a part-time student. All the graduates of the PhD programme have found suitable employment and it was thought by the Chairman that the Department could 'produce and place' two or three PhDs per year if they could enrol enough suitably qualified students in the programme. They receive over 100 applicants each year but only 4 or 5 from Canadian students and there seems to be no prospect of this situation improving in the near future.

Canadidates for the PhD degree are required to take a minimum of the equivalent of four half courses. Sixteen graduate courses are listed in the catalogue. These provide a good coverage of physical metallurgy, some coverage of materials science (the colloquium on the Physics and Chemistry of Solids, held in conjunction with graduate courses in the Department of Physics and the Department of Chemistry, is an encouraging sign of interdisciplinary activity) a barely adequate coverage of extractive metallurgy and no coverage of ceramics or polymers. The range of courses offered in materials science is extended a little by the inclusion of a Chemical Engineering course in statistical thermodynamics and a course in applied surface chemistry offered by the Mining Department. Similarly, extractive metallurgy is extended by inclusion of the same two courses, a chemical engineering course in mathematical models of mineral processes and optimization methods for mineral processes. However, there are no courses in some important areas of extractive metallurgy such as fluid dynamics, heat and mass flow, and electrometallurgy.

It was clear from our conversations with the students that the range and variety of courses available to them is not even as great as appears from a reading of the catalogue. Because of the small number of graduate students in each year of study, most of the courses are given every second year or even less frequently. The sixteen courses listed are taught by only seven professors and, inevitably, faculty members are teaching some courses in subject areas in which they have little research experience. It was very clear to us, however, that the small group of faculty members teaching in the graduate programme are talented, enthusiastic and dedicated people. One or two of them were carrying much larger teaching loads than would be normal in a larger department and we discovered several instances in which graduate courses had been taught on a regular schedule to only one or two students. On the other hand, we also heard from a number of the students specializing in extractive metallurgy that they were obliged to take courses unrelated to their field of study in order to satisfy the general requirements because these were the only courses available.

The department has one of the strongest undergraduate programmes in the Province, graduating 15 to 20 students each year with BSc degrees in Metallurgical Engineering.

The Department is well staffed and well equipped to carry out this work and would be helped by the opportunity to teach a materials course to all freshmen engineers.

In summary, the doctoral programme in extractive metallurgy, although taught by well-qualified and effective faculty members is inadequate in its present form. The range of courses offered is too small. The research activity, although of good quality, is too limited in its variety. The interactions between students and faculty members in extractive metallurgy and those in related disciplines such as Mining and Mineral Engineering and Chemical Engineering are ineffective. The programme attracts only a very small group of qualified students and few of these are from Canadian undergraduate programmes. There are, however, at least two reasons why the doctoral programme in extractive metallurgy at Queen's should be developed and strengthened. For the reasons discussed earlier, PhD graduates will be needed in the years ahead by the mineral and metallurgical industries in Canada. A majority of the graduates needed will have to be produced in Ontario and the output from Toronto and McMaster Universities is not likely to be sufficient to meet the future demand. Queen's has for many years had a good undergraduate programme in metallurgy from which many operating and supervisory staff in Canadian extractive metallurgy industries have graduated. The University has a history of leadership in Canada in mineral engineering, geology and related fields. The programme in extractive metallurgy should build on these strengths. There seems to be little doubt that the separation of mineral engineering and metallurgy weakened the effort in extractive metallurgy. Ways should be found whereby the two groups can be put together again to develop an imaginative doctoral programme designed to fit the future needs of the Province. The faculty members in Chemical Engineering should also be intimately involved in this new initiative.

The doctoral programme in physical metallurgy is a good programme of a traditional type taught by young and talented faculty members but it is not a programme in materials engineering. Even within the range of traditional physical metallurgy it puts great emphasis on mechanical physical metallurgy and this activity is likely to be further emphasized when collaboration with faculty members in Mechnical Engineering on projects concerned with extrusion and machinability develops. There is, of course, a need for a few specialists in physical metallurgy and, no doubt, the programme at Queen's will continue to attract a few good students and to graduate a few PhDs with this type of specialized knowledge. There seems to be no reason to perturb the situation. However, although the programme in physical metallurgy would probably provide a suitable basis from which to expand, by adding faculty members in polymers and ceramics, into a programme in materials engineering, it is not recommended that this step be taken at the present time because the necessary supporting effort in materials science in the university is inadequate and in disarray.

Attempts to develop an interdisciplinary doctoral programme in materials science at Queen's appear to have been unsuccessful. Probably, in the next five years, only one full programme in materials science in the Province will be needed and can be justified. This need will be met adequately by McMaster. An attempt to revive materials science at Queen's cannot be supported at the present time.

Recommendations

1. The programme in extractive metallurgy be replaced by an enlarged programme in extractive metallurgy and mineral engineering developed jointly by faculty members from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology.
2. The PhD programme in physical metallurgy be maintained.

University of Waterloo

There is no graduate programme in materials at the University of Waterloo and consequently there is no PhD degree in metallurgical engineering or any allied field. The undergraduate enrolment in engineering is the largest of any school in the Province and the number of graduate students enrolled in engineering departments is second only to Toronto. At the undergraduate level the programme is a unique co-op plan and at the graduate level cooperation with industry is extensive and effective.

There is a group of six or seven faculty members, five in the Department of Mechanical Engineering, each of whom was trained as a metallurgist or materials scientist, who do research on such problems as fatigue, solidification, properties of bone, machining, welding, forming, creep, ductile fracture, strain, ageing, and interfaces. The five faculty members in Mechanical Engineering received last year a total of $114,725 in industrial and governmental research grants. They are, and consider themselves to be, materials engineers working in a Mechanical Engineering Department on mechanical engineering problems. However, most of their students consider themselves to be mechanical engineers with a special interest in a particular class of materials, or a special materials problem, studying for a PhD degree in Mechanical Engineering. Although there is close cooperation between the faculty members in Mechanical Engineering working on, for example, metal-working problems and those in the materials group, all the research we saw under the direction of professors in the group was strongly focussed on a materials problem and was indistinguishable from research carried out in physical metallurgy or materials science departments in other universities. The group offers graduate courses in mechanical metallurgy, thermodynamics, phase transformations and composite materials, all of which could be found in the curriculum of any good department of physical metallurgy, or as courses contributing to an interdisciplinary programme in materials science. The faculty members in the group are well qualified, young and productive. Their research is imaginative, although the topics are traditional, and several of them are achieving an international reputation.

There are materials courses offered by other engineering departments. For example, under Civil Engineering, courses listed include, "Advanced Topics in the Behavior of Materials and Fracture Behavior of Materials" and, under Chemical Engineering, "Principles of Polymer Science and Physical Properties of Polymers". We were left with the strong impression that, if the faculty members and courses concerned with materials were brought together in an administrative unit, Waterloo would probably have the strongest and most comprehensive graduate programme in materials engineering in the Province and, furthermore, one which would have the great advantage of being an integral part of a vigorous engineering school. Obviously, this concept has received some attention inside the university. The deans and department chairmen we interviewed expressed their lack of enthusiasm for the idea with various degrees of intensity. From the start of the Faculty of Engineering at Waterloo there has been strong opposition from both the administration and the faculty members to small groupings and 'empires'. There was, and still is, opposition to the formation of the only interdepartmental group in the Faculty, the Solid Mechanics Group. Even today this group is only a 'graduate division'. It does not have a 'head', only a 'spokesman'! However, in conversations with some of the most active younger faculty members we detected some impatience with the traditional attitudes of the administration and some of their older colleagues on this point. They believe that a materials engineering group would give greater visibility to their work, be a more appropriate unit than the Department to which to look for evaluation and support when they are under consideration for tenure, promotion or other rewards, would promote interaction between faculty with a primary interest in materials engineering problems, and lead to a more balanced and meaningful programme for the graduate students interested in engineering materials. We agree with these views. We recommend that the Faculty of Engineering be urged to reexamine the proposition that some administrative and organizational structure be developed to give coherence and visibility to a graduate programme in materials engineering.

In the Physics Department there are a number of faculty members whose primary research interest is in a materials problem. Their interests cover such topics as parameters of crystal lattices, thin films, lattice dynamics, diffusion in III-IV compounds and crystal imperfections in semiconductors. A distinguished member of this group was at one time a professor of metallurgy and chairman of a materials research unit at another Canadian university. The Physics Department lists graduate courses in "Crystallography, Stability and Properties of Metallic Phases and Crystal Structures, Electron Microscopy and Electron Diffraction, Solid State Physics, Imperfections in Crystals, Crystal Physics" and other courses of central importance in materials science. Some of the students in the Engineering Faculty take some of these courses but we did not find any evidence that a significant number of students in Physics benefit from some of the excellent courses in materials in Engineering. No Materials Research Centre has been developed in the university nor have centralized research facilities been established, although there are some informal arrangements for sharing equipment. Some administrators expressed the view that they did not need to adopt this 'device' for obtaining funds for equipment.

The faculty members working on materials problems in the departments of Physics, Chemistry, Mechanical Engineering, Civil Engineering and Chemical Engineering, when considered together, certainly constitute one of the largest, and amongst the most talented, group of materials scientists and engineers to be found at any of the universities in Canada. Nearly all the courses needed to make a first-rate programme in materials science already exist in the university. Unfortunately, we could find no reason to hope that a coherent interdisciplinary effort in materials science would emerge at Waterloo in the near future. There appears to be no desire on the part of the administration to foster organizations which cut across departmental or school boundaries. Nor is there any evidence that an appreciable number of the faculty members want to participate in such an interdisciplinary effort. We feel that there exists at Waterloo the opportunity for the university to play a major role in the development of materials science. It is regrettable that the university has decided to apply its energies and resources elsewhere.

Before leaving Waterloo we must also comment upon the activities in extractive metallurgy in the Department of Chemical Engineering. "Extractive and Process Metallurgy" is listed as one of seven areas of research in the department. There are five faculty members working in the area and two others who have a secondary interest. Two of the faculty members were trained as metallurgists, the others received their graduate degrees in chemical engineering. About fifteen graduate students in Chemical Engineering are doing research in extractive or process metallurgy and an extensive array of graduate courses in the area is provided for these and other students. There is also an undergraduate 'option' in extractive metallurgy within the Chemical Engineering programme. Thus, the total graduate registration in extractive metallurgy is larger than that in any other university in the Province. We see no disadvantages in having the group within Chemical Engineering provided they have effective interactions with metallurgists in other departments. In fact, there are some clear benefits to be gained by combining the skills and ideas of the metallurgist and the chemical engineer.

The faculty members teaching extractive and process metallurgy in the Chemical Engineering Department emphasized that they thought of themselves as chemical engineers and of the graduates of the 'option' as chemical engineers with special knowledge in extractive metallurgy. The faculty members stated that they were not 'accepted' by the professional community of extractive metallurgists in Canada and that, for example, they had not been able and now did not wish to publish their papers in Canadian metallurgical journals. However, the graduates, both at the BSc and PhD level, of their programmes appear to find no difficulty in finding employment in the mineral and metallurgical industries where, undoubtedly, they constitute an important contribution to the engineering and scientific staffs of these industries. Clearly, the industry recognises the value of the 'option' even if the 'profession' does not. In our view the graduate programme in extractive and process metallurgy within the Department of Chemical Engineering is a good programme which should continue to receive strong support from the university.

University of Western Ontario

The engineering school at the University of Western Ontario, described as the Faculty of Engineering Science, is small. Although it contains only about 40 faculty members, organizationally it is divided into 'groups', which reflect the divisions within the engineering profession. One of these small groups is the materials science group. There are four associate professors, one of whom is the chairman, and one full professor in the group. They offer a "Materials Science Option" in the undergraduate programme in Engineering Science with courses in the third and fourth year as well as more general courses in materials designed for undergraduate engineering students. About 6 or 8 students graduate from the materials science option each year. In addition there is a materials science programme at the graduate level in which there are currently enrolled 6 MESc and 4 PhD candidates. All the master's candidates will take the degree by thesis and most will continue to the PhD. There is provision for students to take the MESc by course work alone but no students in materials science have elected this programme. The group is well housed in a pleasant building and is well equipped for undergraduate and graduate teaching.

Research at the University of Western Ontario is organized in centres that interweave internally and with local industry and the medical world. Most formal perhaps is the Centre for Interdisciplinary Studies in Chemical Physics supported by an NRC Negotiated Development Grant. This centre is located in the physics bulding and is headed by the Chairman of the Physics Department. At present, the two major fields of interest are energy deposition studies for therapeutic uses and thin films. At least two members of the materials science group are active members of the Centre. Other, perhaps less formally organized, research groups are those in Geotechnical Engineering and in Applied Electrostatics. Members of the materials science group contribute to both of these. However, at the present time only two members of the group are actively engaged in research. One of the others is on sabbatical leave. The two associate professors who are active are carrying out productive and imaginative work. Not surprisingly, they are the two members of the group who interact most strongly with, and make significant contributions to, the work of the research centres for chemical physics, geotechnical engineering and applied electrostatics. Five graduate students participate in cooperative programmes with industry.

A student is required to take four half-courses for the MESc by thesis. For the PhD, twelve half-courses are required, including courses taken at the master's level. Six of the twelve courses have to be courses offered by the group of faculty members in materials science. Twelve such courses are listed in the Calendar for 1973-74. Of these, six courses are devoted to experimental techniques, "Spectroscopy, X-ray Techniques and Advanced Experimental Techniques" and cover topics which usually are taught in a laboratory course or in courses offered by engineering physics departments. They are certainly useful courses for a student in materials science but together they make up only a small part of the core of materials science. One of the six remaining courses is entitled "The History of Materials Science." The other five are courses which, nor surprisingly, reflect the special interests of the faculty. They will give the student a useful insight into certain aspects of materials science but the range of subjects considered at sufficient depth to allow the student to select a balanced programme in materials science is far from adequate. The faculty members expressed the view that the six courses taken outside the group fill some of the gaps but we could find no evidence of the existence in physics or chemistry of a significant number of courses which would be an important contribution to the core of materials science programme. The situation with regard to the courses offered by the faculty members in the materials science group is worse than represented by the calendar because, due to the small number of students, many of the courses are offered infrequently. The group tries to offer eight half-courses at the graduate level per year and aims to have at least five students in each course by attracting students from other groups. Too frequently it fails to achieve even this modest programme. The failure is not due to any lack of effort in the graduate programme. They are good engineers and scientists who, unfortunately, find themselves carrying a large programme for a group which is subcritical in size.

The existence of a graduate programme in materials science is not evident from an examination of the calendar. There, all the graduate faculty members in Engineering Science are listed alphabetically and the courses are listed in numerical order. Some members of the administration of the Faculty of Engineering Science with whom we spoke emphasized that the only PhD programme in the Faculty is a programme in Engineering Science. They added that the active faculty members in the materials science group make an important contribution to teaching in the larger programme. The course in "Advanced Experimental Techniques", for example, is valuable to students with interests ranging over many different areas of Engineering Science. Further, these faculty members make important contributions to the research work in the Faculty and the University, particularly in geotechnical engineering, applied electrostatics and chemical physics. Their efforts should be supported to enable them to continue to make effective contributions to the programme in Engineering Science. Graduate students working with them should be encouraged to take a combination of courses which would give them a more general education in Engineering Science. The restriction that requires their students to select six half-courses from those offered by faculty in the materials science group should be removed.

We recommend that the graduate effort be directed towards the development of strong interdisciplinary context rather than an exclusively materials science programme.

University of Windsor

There is a Department of Engineering Materials but the PhD programme in engineering materials has been absorbed by the new divisional programme. The Faculty of Engineering is small with less than 40 full-time staff members and about 70 graduate students of whom 30 are candidates for the PhD degree.

The staff of the Department of Engineering Materials consists of three full professors (one of whom is on leave from the University), one full-time associate, one part-time associate and one assistant professor. Their research interests, which are interrelated to a substantial degree, include metal-working processes, kinetics of phase transformations in alloys, strengthening mechanisms in and fatigue of metals and alloys and creep of some ceramic materials. The work is well supported financially by NRC and DRB and most of the projects are carried out with the collaboration, and in some cases, the financial support of local (including Detroit) industry. Much of the research has a strong engineering flavour and interactions between the faculty members in Engineering Materials and in other engineering departments are frequent and effective. Three members of the Department are very productive, judged by their current rate of output of papers in refereed journals.

The graduate programme in engineering recently has been organized into three divisions: Engineering Process Design, Structures, and Systems. Each division offers about 20 courses from which the student can select a programme with the advice of his doctoral committee. Faculty members in the Department of Engineering Materials contribute to one joint course in the Engineering Process Design Division and five courses (including one of the core courses) in the Structures Division. This arrangement of the graduate work has not been in existence long enough to allow a judgment of its effectiveness to be made. In this first year the faculty members seem to be having more difficulty with it than the students. Some of the older staff find it difficult to divide their loyalties between the Department and the graduate division but these problems are likely to disappear when confidence in the effectiveness of the divisions is established. The graduate students see the divisions as a means of providing a focus for their studies and welcome the opportunity to be involved with a broad spectrum of engineering research.

In our view the divisional programmes have been put together in a logical fashion. Each division provides a good coverage of a coherent area of engineering and the teaching and research of the faculty members in Engineering Materials should make an excellent contribution to the work of the Structures Division.

We recommend that the efforts of the faculty members of the Department of Engineering Materials to integrate their graduate work with that of the Divisions of Structures and of Engineering Process Design should be encouraged and supported financially.

Inter-University Cooperation in the Province of Ontario

An exchange scheme for graduate courses already exists in Ontario through which students registered at a given university may take courses offered at another university within the Province. The arrangement requires the concurrence of the graduate faculties of both universities and the payment of an inter-university course transfer fee. Similar facilities for course transfer are available in the Province of Quebec. Such an arrangement seems to us to be a desirable one, and could be particularly beneficial to students in neighbouring universities. The potential for the pooling of some specialties, for example in the Toronto-McMaster-Waterloo triangle, is one that is apparent and consideration should be given to making greater use of the existing machinery for these transfers. Examples of existing specialties which could be pooled between universities are: non-ferrous extraction metallurgy at Toronto, ferrous extraction metallurgy at McMaster, courses with a Materials Engineering flavour at Toronto and Waterloo, and courses with a Materials Science orientation at McMaster. The complementary nature of the offerings presently available is striking and it seems to us that graduate programmes of higher quality could be assembled at the individual universities if more use were to be made of the unique and specialized courses now taught at various universities within the Ontario network.

In addition to course transfer, it appears to us that much would be gained if a TV talk-back network were to be made available to the universities that we visited. In such an event, travel between campuses would be eliminated, (an advantage in February!) and students in the universities beyond the Toronto-Hamilton corridor would also be able to participate.

The expense involved in setting up some of the newer experimental facilities in the materials area raises the possibility of shared or joint centres and laboratories. An example of such an instrument is the projected scanning-transmission electron microscope, which would appear to be a good candidate for inter-university support. Once again, the Toronto-McMaster-Waterloo triangle comes to mind. However, as an alternative to locating the facility at one of the three universities, some attention should be given to the use of the research 'campus' at Sheridan Park, which is so centrally located.

We recommend that more attention be given to inter-university cooperation in the Metallurgy and Materials field in Ontario: such collaboration could take the form of coordinated course transfer at the graduate level, of the use of a TV talk-back network for graduate instruction and seminars, and of the shared construction and operation of expensive research facilities.

LIST OF APPENDICES

Appendix 1	Terms of Reference
2.1	"Report on Doctoral Studies in Metallurgical and Materials Engineering in the Province of Ontario", Committee of Heads of Ontario Metallurgical and Materials Engineering Departments.
2.2	Table showing the steady-state population of graduate students and post-doctoral scientists and engineers expected in Ontario in the period 1973-78. Data from Appendix 2.1.
3.	Manpower Table 1. Distribution of PhD's on AECL staff at August 1973 by discipline and by year of PhD in 5-year groups. Table 2. Number of PhD's on AECL staff at August 1973 by date of appointment and by date of PhD degree. Table 3. Graduate students (full- and part-time) in departments of Metallurgy and Materials Science in Ontario classified according to the part of the world in which they received their first degree.
4.	Summary of data relating to "Metallurgical Engineering" collected by ACAP.
5.	Canadian Association of Graduate Schools press release, 14 December 1972. "Employment of new PhD graduates, 1971-72".

Appendix 6. Metallurgical Engineering Doctoral Planning Assessment - McMaster University.

7. Metallurgical Engineering Doctoral Planning Assessment - University of Toronto.

8. Metallurgical Engineering Doctoral Planning Assessment - Queen's University.

9. Mechanical Engineering Doctoral Planning Assessment - University of Waterloo.

10. Metallurgical Engineering Doctoral Planning Assessment - University of Western Ontario.

11. Metallurgical Engineering Doctoral Planning Assessment - University of Windsor.

NOTE: Appendices 6 through 11 are the data submitted by the individual universities to ACAP. They are not reproduced in this report but are available at the offices of COU.

APPENDIX 1

Terms of Reference of Consultants

1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering Ph.D. Planning and Assessment Procedures, Statement on Ph.D. Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

2. Report on the adequacy of the present state of doctoral work in "metallurgical engineering" in the province in general and in each university where applicable, discussing the following:

   a. coverage of fields and specialties, and extent of activity in each

   b. faculty quality and quantity

   c. nature of programmes offered

   d. enrolment size and distribution amongst universities and divisions

   e. quality of student body; admission requirements

   f. relationship to related disciplines and to the profession

   g. physical facilities

   h. other matters considered by the consultants to be significant.

3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

   a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study in metallurgical engineering and in the major subject divisions where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section C3 (c).

APPENDIX 2.1

COMMITTEE OF HEADS OF ONTARIO
METALLURGICAL AND MATERIALS ENGINEERING DEPARTMENTS

Report on Doctoral Studies
in
Metallurgical and Materials Engineering
in the
Province of Ontario

May 16, 1973

Report on Doctoral Studies
in
Metallurgical and Materials Engineering
in the
Province of Ontario

INTRODUCTION

This report has been prepared by the Metallurgical Engineering Discipline Group, which includes the Heads of Metallurgical and Materials Engineering Departments in the Province of Ontario, viz., McMaster, Toronto, Queen's, Western, and Windsor. Its central function is to provide the Consultants to ACAP for Metallurgical Engineering planning with the Discipline Group's collective views regarding the plans for doctoral programs in Metallurgical and Materials Engineering in the Province of Ontario. The presentation of this report complies with section 3 of the "Engineering Ph.D. Planning and Assessment Procedures" document as drafted by the Coordinating Task Force, which stipulates that each Discipline Group prepare "...a report on Ph.D. activities and plans in their discipline area, noting both apparent conflicts and gaps in both areas of specialization and enrolments."

SUMMARY OF INSTITUTIONAL STATEMENTS

A summary of the institutional plans, taken in alphabetical order, is given below. The major research programs now in progress at each institution are categorized under the three principal sub-disciplines: Extractive (Chemical) Metallurgy, Physical Metallurgy, and Materials Research. The numbers of full time equivalent M.A.Sc.'s, Ph.D.'s, and P.D.F.'s or R.A.'s (Research Assistants) are also listed opposite each research program to give some indication of its relative importance in the Department. In general, the 5 year plans as reported by the various institutions tend to project the research now in progress, and are based on the assumption that the current financial constraints will not be substantially alleviated.

MCMASTER UNIVERSITY

Extractive (Chemical) Metallurgy	M.A.Sc.	Ph.D.	P.D.F. and R.A.
Pyrometallurgy	3	6	1
Hydrometallurgy	-	-	-
Oxidation and Corrosion	3	3½	3
Mineral Processing	-	-	-
Physical Metallurgy			
Phase Transformations	2	1	-
Solidification	-	-	1
Mechanical Properties	-	3	2
Alloy Development	-	-	-
Mechanical Processing	-	-	-
Diffusion	1	-	-
Powder Metallurgy	-	-	-
Metal Joining	-	-	-
Liquid Metals	-	-	1
Materials Research			
Polymers	-	-	-
Ceramics and Glass	4	1	2½
Metal Physics	1	2	-
Composites	-	1	-
Electronic Materials	1	1½	-
Biomedical Materials	-	-	-
TOTALS	15	19	10½

QUEEN'S UNIVERSITY

	M.A.Sc.	Ph.D.	P.D.F. and R.A.
Extractive (Chemical) Metallurgy			
Pyrometallurgy	-	-	-
Hydrometallurgy	-	-	-
Electrometallurgy	-	-	-
Corrosion & Oxidation	2	1	-
Mineral Processing	-	1	-
Physical Metallurgy			
Solidification	2	1	2
Phase Transformation in the Solid State	-	-	-
Mechanical Properties	-	2	1
Alloy Development	-	1	-
Mechanical Processing	-	-	-
Diffusion	-	-	-
Powder Metallurgy	-	-	-
Metal Joining	-	-	-
Liquid Metals	-	-	-
Materials Research			
Polymers	-	-	-
Ceramics and Glass	-	-	-
Composites	-	-	-
Metal Physics	-	1	1
Electronic Materials	1	-	-
Bio-medical Materials	-	-	-
TOTALS	5	7	4

UNIVERSITY OF TORONTO

	M.A.Sc.	Ph.D.	P.D.F. and R.A.
Extractive (Chemical) Metallurgy			
Pyrometallurgy	8	4	2
Electrometallurgy	4	2	2
Hydrometallurgy	1	-	-
Corrosion	-	-	1
Mineral Processing	-	-	-
Process Metallurgy	1	-	-
Physical Metallurgy			
Phase Transformations	-	2	-
Solidification	2	2	-
Mechanical Properties	-	2	-
Alloy Development	1	-	1
Mechanical Processing	2	-	-
Diffusion	1	-	-
Powder Metallurgy	2	1	1
Welding	-	-	-
Liquid Metals	1	-	1
Materials Research			
Ceramics and Glass	-	-	2
Polymers	-	-	-
Composites	-	1	-
Electronic Materials	-	-	2
Biomedical Materials	-	-	-
TOTALS	23	14	12

UNIVERSITY OF WESTERN ONTARIO

	M.A.Sc.	Ph.D.	P.D.F. and R.A.
Extractive (Chemical) Metallurgy			
Oxidation and Corrosion (including Protective Coatings)	0	1	2
Mineral Processing (with the Electrostatics Group - by Electrostatic Processes)	1	1	1
Physical Metallurgy			
Phase Transformations	1	0	0
Mechanical Properties	1	0	0
Wear	0	0	1/3
Materials Research			
Electronic Materials (Electrical and Magnetic Properties of Thin Films)	1	2	0
X-Ray Generation	0	1	0
Composites	1	0	1/3
TOTALS	5	5	3 2/3

UNIVERSITY OF WINDSOR

Physical Metallurgy	M.A.Sc.	Ph.D.	P.D.F. and R.A.
Mechanical Processing (Thermo-mechanical Processing of Non-Ferrous Alloys)	-	1	1
Mechanical Properties (Deformation Processes and Fracture in Solids)	-	-	1
Solidification (Nucleation, Crystal Growth and Segregation Mechanisms)	-	-	1
Diffusion	1	-	-
Materials Research			
Ceramics	-	-	1
Biomedical Materials (Dental Alloys)	-	-	1
Electronic Materials (Electrical and Magnetic Properties of Thin Films)	-	-	1
TOTALS	1	1	6

COMMENTARY ON PLANS

Research Projections:

As previously indicated, the statements as outlined by the various institutions and summarized in this report are essentially projections of present research programs. These programs are funded principally by one of two sources: government bodies (NRC, DRB, AECL, etc.), and industry. In the case of government funded projects, continued financial support is dependent on the favourable recommendations of a special committee which looks into the significance and revelance of the research and the competence of the grantee in question, as determined primarily by performance records. In the case of industry funded research, the support is based almost wholly on the relevance of the research to a particular industrial problem or goal, as well as the demonstrated ability of the grantee to direct or perform the research. Thus, it is fair to say that the research programs now in progress, along with the corresponding student enrolments, are not characterized by overemphasis or redundancy in any particular area of specialization. Overemphasis or redundancy could creep into certain broadly designated areas of government funded research; however, even here this possibility is remote because of the screening processes to which all applications for research grants are subjected. In the absence of any detailed figures on manpower and resource allocations, as well as other economic factors, the Metallurgical Engineering Discipline Group is not prepared to make any categorical statements regarding gaps in areas of specialization, although individual members of the Group may have personal views on the matter based on their limited experiences.

Projected Student Enrolment:

With regard to the projected student enrolment in the doctoral programs, the Metallurgical Engineering Discipline Group takes the position that the desirable number of Ph.D. students within the Ontario System is predicated on two plausible factors. One is the number of Canadian students who want, i.e., have the intellectual need for, this education. At present, and in the foreseeable future, it is unlikely that Canadian student demand will produce a sufficient number of Ph.D. students to accommodate the second factor: the number of graduating Ph.D. students required by our society. In the past, this need was mainly for university teachers and for research in the more sophisticated technologies of some of the government research laboratories. At present and for the next five years, the main need will be in industry, which is now recognizing the increasingly rapid change in technology. Either foreign students must be brought into our Ph.D. programs or industry must hire foreign Ph.D. graduates. It is recommended that the present number of Ph.D. students enrolled in the system (approximately 50 - see totals in

Institutional Statements) be maintained over the next three years for supply to meet anticipated demand, and that this figure may have to be increased in subsequent years depending on the job situation, especially for students with a non-western background. At this time the Group feels it essential to put on record its collective experience that Ph.D. graduates with a non-western background are considerably more difficult to place in industry.

Educational Goals and Style:

The educational goals of each institution are, in general, similar and only vary slightly in their wording. The principal goal is to develop the student's potential for defining and solving complex engineering problems, which more and more require interdisciplinary approaches. The styles in which the stated goals are to be attained vary of necessity from institution to institution, because of the different structures of the respective faculties and varied background and interests of the faculty.

SUMMARY

The projected research plans and student enrolments in the graduate programs for the various institutions, as summarized in this report, should not be taken as irrevocable committments to research only in those areas and at the student levels indicated. The broad training and varied experience of the faculty members permits considerable flexibility in the choice of research projects, and changes can and will be made should national or provincial priorities so require.

APPENDIX 2.2

Table showing the steady-state populations of graduate students and post-doctoral scientist and engineers expected in Ontario between 1973 and 1978 classified by the materials studied. Data from Appendix 2.1.

	MASc	PhD	Post-Doctoral Fellows
Extractive (Chemical) Metallurgy	23	19.5	12
Metals (other than extractive met.)	17	17	14.3
Ceramics and Glasses	4	1	5.5
Polymers	0	0	0
Electronic Materials	3	3.5	3
Composites	1	2	0.3
Biomedical Materials	0	0	1
TOTALS	48	43	36

APPENDIX 3

Table 1 showing distribution of PhDs on AECL staff at August 1973
by discipline and by year of PhD, in 5-year groups
(except 5½ years for 1968-73 and 11 years for 1932-42)

PhD Degree Dates	Total on Staff	Life Sciences	Physical Sciences	Engineering	Metallurgy and Materials	Metall. Engrg.	Chemical Engrg.	Mechanical Engrg.	Nuclear Engr.	Electrical and Electronic Engr.	Civil Engrg.	Engrg. Phys.	Other Engrg.
68-73	105	1	50	54	15	7	12	17	6	4	1	4	3
63-67	76	3	53	20	10	1	4	3	2	1	0	6	3
58-62	21	3	17	1	2	0	1	0	0	0	0	0	0
53-57	27	3	17	7	2	1	2	1	0	0	0	2	1
48-52	29	2	19	8	0	0	4	0	0	0	2	2	0
43-47	8	3	5	0	0	0	0	0	0	0	0	0	0
32-42	5	3	2	0	0	0	0	0	0	0	0	0	0
Total	271	17	164	90	29	9	23	21	8	5	3	14	7

APPENDIX 3

Table 2 showing numbers of PhDs on AECL staff
at August 1973 by date of appointment
and by date of PhD degree

By Year of Appointment Total	Year	By Year of PhD Degree		
		Total	Physical and Life Sciences	Engineers
* 13	1973	* 7	* 3	* 4
18	72	* 7	* 2	* 5
29	71	20	6	14
32	1970	25	10	15
17	69	21	11	10
21	68	25	19	6
19	67	21	17	4
19	66	17	12	5
6	1965	12	9	3
12	64	17	13	4
10	63	9	5	4
8	62	6	6	0
4	61	7	7	0
4	1960	3	3	0
3	59	1	1	0
4	58	4	3	1
4	57	5	3	2
4	56	7	5	2
4	1955	3	2	1
5	54	8	7	1
1	53	4	3	1
34	Before 1953	42	42	0
Total 271		271	181	90

Note the different patterns and in particular the relatively recent growth in number of Engineer PhDs. Asterics indicate numbers still increasing significantly.

APPENDIX 3

Table 3 Graduate students (full and part-time) in departments of Metallurgy and Materials Science in Ontario classified according to the part of the world in which they received their first degree.

	Master's					PhD				
Year	Total	Canadian	%	Asian	%	Total	Canadian	%	Asian	%
68/69	55	27	49	15	27	55	28	51	10	18
69/70	54	17	31	17	31	53	29	55	11	21
70/71	49	12	25	21	43	49	22	45	11	22
71/72	43	13	30	16	37	43	14	33	13	30
72/73	46	22	48	9	20	44	11	25	14	32

APPENDIX 4

METALLURGICAL ENGINEERING
DOCTORAL PLANNING ASSESSMENT

Comments on Systems Total

1. Form 3 contains no figures for actual faculty for all years at McMaster and Toronto, since these numbers were only given by specialty and include some double counting.

2. Form 4 contains no number of undergraduate courses for Toronto in 1972-73.

3. Form 8, the financial support, does not agree with the totals of full-time students on Forms 3 and 7 for the following reasons.

Windsor:	1968-69	shows	12	F.T.	students	on	#3	& 7	but	supports	11
	1979-70	"	10	"	"	"	"	"	"	"	9
Toronto:	1969-70	"	35	"	"	"	"	"	"	"	36
	1970-71	"	32	"	"	"	"	"	"	"	34
	1971-72	"	31	"	"	"	"	"	"	"	33
					(column is added incorrectly)						
	1972-73	shows	39	F.T.	students	on	#3	& 7	but	supports	42

4. Forms 7, 9 and 10 do not agree as to the number of doctoral degrees awarded, employment and time to reach degree for 1971-72 because Western's submission is missing forms 9 and 10 for this year and Queen's shows 4 degrees awarded, 3 employed and 4 on the time to reach degree form.

If any of these errors or omissions can be corrected, please do so by letter before May 16

NOTE: Western originally showed 1 PhD granted in 1971-72. Dr. J.D. Brown corrected it to no degrees awarded. Therefore, the number of FT PhDs awarded in 1971-72, Form 7, should read 7 not 8.

APR 26 1973

Form 3

A-61 UNIVERSITY SYSTEM TOTAL

INCLUDES: McMASTER, QUEEN'S,
TORONTO, WESTERN and
WINDSOR.

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

POPULATIONS (1)

POPULATION		1968-69	1969-70	1970-71	1971-72	1972-73 (est.)
FACULTY (2) *	F.T.	16	18	19	19	19
	P.T.	1				
ASTERS UDENTS (3)	F.T.	54	48	43	37	42
	P.T.	1	6	6	6	4
DOCTORAL STUDENTS	F.T.	54	49	45	38	40
	P.T.	1	4	4	5	4
POST-DOCTORAL FELLOWS		3	5	4	3	4

(1) As of December 1.

(2) Includes assistant professors and up. If a faculty member spends time in two divisions, count him once in each. Do not use a percentage. A part-time faculty member is one defined as such by the university at time of appointment. All faculty counted here appear on Form 1 and CV's are included.

(3) This does not include make-up and qualifying year students.

* DOES NOT INCLUDE McMASTER and TORONTO

APR 2 [illegible]

Form 4.

UNIVERSITY SYSTEM TOTAL

A-62

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

UNDERGRADUATE ACTIVITY

	1967-68	1968-69	1969-70	1970-71	1971-72
No. of Bachelor Degrees Granted in this Specialty Field or Department(1)	24	36	37	33	44
No. of Make-up or Qualifying Year Students(2)				1	
No. of B.Sc.s Granted in Engineering Science, Engineering Physics	47	46	73	50	85
No. of Undergraduate Courses Taught(3)	8,097	10,830	11,457	9,694	10,588 *

(1) Degrees granted during the year September to August 31 of the year indicated.

(2) As of December 1.

(3) This is the product of the number of courses taught and the number of students enrolled therein.

A "course" is a semester course - 13 to 15 weeks, approximately 40 to 50 hours. (A full course should be counted as two courses.)

* DOES NOT INCLUDE TORONTO

Form 7.

UNIVERSITY SYSTEM TOTAL

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENT DATA[1]

1968 - 69

LEVEL		IMMIGRATION STATUS	COUNTRY OF 1ST DEGREE						NUMBER DROPPED OUT (2)	DEGREES AWARDED (3)
			CANADA 1	USA 2	UK - AUST. 3	ASIA 4	OTHER 5	UNKNOWN 6		
MASTERS	54 F.T.		27	2	6	15	4		2	21
	P.T. 1				1					
DOCTORATES	54 F.T.		27	3	7	10	7		1	6
	P.T. 1		1							
TOTAL	F.T.									
	P.T.									

---

(1) As of December 1, the number of registered students.

(2) A drop out is defined as a student who has not obtained his degree and does not register for the next academic year.

(3) During the year, September 1 to August 31.

APR 26

Form 7.

UNIVERSITY [illegible]

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENT DATA (1)

1969-70

A-64

LEVEL		IMMIGRATION STATUS	COUNTRY OF 1ST DEGREE						NUMBER DROPPED OUT (2)	DEGREES AWARDED (3)
			CANADA 1	USA 2	UK - AUST. 3	ASIA 4	OTHER 5	UNKNOWN 6		
MASTERS	F.T. 48	Canadian	15		1					21
		Landed Immigrant	1		2	10	9			
		Student Visa		1	3	5				
		Other				1				
	P.T. 6	Canadian				1				
		Landed Immigrant	1		4					
		Student Visa								
		Other								
DOCTORATES	F.T. 49	Canadian	27				1		1	10
		Landed Immigrant		2	2	6	1			
		Student Visa		2	1	5	2			
		Other								
	P.T. 4	Canadian	2							
		Landed Immigrant		1			1			
		Student Visa								
		Other								

(1) As of December 1, the number of registered students. Note the total of columns 1 to 6 must agree with that given on Form 3.

(2) A drop out is defined as a student who has not obtained his degree and does not register for the next academic year.

(3) During the year, September 1 to August 31.

APR [illegible]

FORM 7.

UNIVERSITY System [illegible]

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENT DATA (1)

1970-71

LEVEL		IMMIGRATION STATUS	COUNTRY OF 1ST DEGREE CANADA 1	USA 2	UK - AUST. 3	ASIA 4	OTHER 5	UNKNOWN 6	NUMBER DROPPED OUT (2)	DEGREES AWARDED (3)
MASTERS	F.T. 43	Canadian	10							16
		Landed Immigrant	1		3	11	8			
		Student Visa			1	2	1			
		Other				1				
	P.T. 6	Canadian	1			2				1
		Landed Immigrant			3					
		Student Visa								
		Other								
DOCTORATES	F.T. 45	Canadian	19				1		1	18
		Landed Immigrant		1	5	7	4			
		Student Visa		2		4	1			
		Other					1			
	P.T. 4	Canadian	3							
		Landed Immigrant		1						
		Student Visa								
		Other								

A-65

(1) As of December 1, the number of registered students. Note the total of columns 1 to 6 must agree with that given on Form 3.
(2) A drop out is defined as a student who has not obtained his degree and does not register for the next academic year.
(3) During the year, September 1 to August 31.

APR 25 1972

Form 7

UNIVERSITY ____________

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENT DATA (1)

1971-72

LEVEL		IMMIGRATION STATUS	COUNTRY OF 1ST DEGREE						NUMBER DROPPED OUT (2)	DEGREES AWARDED (3)
			CANADA 1	USA 2	UK - AUST. 3	ASIA 4	OTHER 5	UNKNOWN 6		
MASTERS	F.T.	Canadian	10	1					1	23
		Landed Immigrant			2	9	7			
	37	Student Visa				5	3			
		Other								
	P.T.	Canadian	3			1			2	1
		Landed Immigrant				1	1			
	6	Student Visa								
		Other								
DOCTORATES	F.T.	Canadian	10				1			8
		Landed Immigrant		1	6	11	6			
		Student Visa			1	2				
	38	Other								
	P.T.	Canadian	4						1	2
		Landed Immigrant		1						
	5	Student Visa								
		Other								

(1) As of December 1, the number of registered students. Note the total of columns 1 to 6 must agree with that given on Form 3.

(2) A drop out is defined as a student who has not obtained his degree and does not register for the next academic year.

(3) During the year, September 1 to August 31.

Form 7.

UNIVERSITY System Total

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENT DATA (1)

1972-73

LEVEL		IMMIGRATION STATUS	COUNTRY OF 1ST DEGREE						NUMBER DROPPED OUT (2)	DEGREES AWARDED (3)
			CANADA 1	USA 2	UK - AUST. 3	ASIA 4	OTHER 5	UNKNOWN 6		
MASTERS	F.T. 42	Canadian	19			1				9
		Landed Immigrant				4	10			
		Student Visa				2	5			
		Other					1			
	P.T. 4	Canadian	3			1				
		Landed Immigrant								
		Student Visa								
		Other								
DOCTORATES	F.T. 40	Canadian	10		1				1	1
		Landed Immigrant			5	10	10			
		Student Visa			1	3				
		Other								
	P.T. 4	Canadian	1						2	
		Landed Immigrant		1	1	1				
		Student Visa								
		Other								

(1) As of October 1, the number of registered students. Note the total of columns 1 to 6 must agree with that given on Form 3.

(2) A drop out is defined as a student who has not obtained his degree and does not register for the next academic year.

(3) During the year, September 1 to October 31.

APR 26 1977

Form 8.

UNIVERSITY S

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

GRADUATE STUDENTS (1)

SOURCES OF FINANCIAL SUPPORT

SOURCES	1968-69	1969-70	1970-71	1971-72	1972-73
NRC SCHOLARSHIPS *	15	4	10	7	9
OTHER MAJOR SCHOLARSHIPS (GREATER THAN $2500)*	12	12	7	8	12
NRC BURSARIES *	5	2	4	3	4
ONTARIO GRADUATE FELLOWSHIPS *	5	2	3	1	2
CIDA (i.e. COMMONWEALTH SCHOLARS, COLOMBO PLAN, etc.)	3	--	3	1	2
FOREIGN GOVERNMENT SUPPORT	1	1			
DEMONSTRATING ONLY			1	1	
RESEARCH GRANT ONLY			2	1	4
DEMONSTRATING PLUS RESEARCH GRANT	49	46	57	50	47
SELF-SUPPORT	1	1	3	2	5
UNKNOWN	16	15			
TOTAL	107	97	90	76	85

(1) Ph.D. and Master's Combined.

* With or Without Additional Earnings

NOTE: As of December 1. (For 1972-73, use October 1.)
Total should equal total full-time enrolment.

UNIVERSITY System [illegible]

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

EMPLOYMENT SURVEY OF PH.D.'s

1968-69 (1)

EMPLOYMENT	IMMEDIATE (2)						AS OF JANUARY 1,					
	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN
UNIVERSITY												
INDUSTRY			2		1							
GOVERNMENT												
COMMUNITY COLLEGE OR HIGH SCHOOL												
FELLOWSHIP					2							
RESEARCH (OTHER THAN FELLOWSHIP)					1							
OTHER												
UNEMPLOYED												
UNKNOWN												
TOTAL			2		4							

(1) For those Ph.D.'s who were granted their degrees during the period, September 1 to August 31 of the year shown.

(2) The first employment obtained within six months of being granted the degree.

6 1973

UNIVERSITY [illegible]

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

EMPLOYMENT SURVEY OF PH.D.'s

1969-70 (1)

EMPLOYMENT	IMMEDIATE (2)						AS OF JANUARY 1,					
	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN
UNIVERSITY					/							
INDUSTRY	/	/	/		/							
GOVERNMENT												
COMMUNITY COLLEGE OR HIGH SCHOOL												
FELLOWSHIP	/				3							
RESEARCH (OTHER THAN FELLOWSHIP)	/											
OTHER												
UNEMPLOYED												
UNKNOWN												
TOTAL	3	/	/		5							

(1) For those Ph.D.'s who were granted their degrees during the period, September 1 to August 31 of the year shown.

(2) The first employment obtained within six months of being granted the degree.

APR [illegible]

UNIVERSITY SYSTEM LAL

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

EMPLOYMENT SURVEY OF PH.D.'s

1970-71 (1)

EMPLOYMENT	IMMEDIATE (2)						AS OF JANUARY 1,					
	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN	ONT.	REST OF CANADA	USA	HOME COUNTRY	OTHER	UNKNOWN
UNIVERSITY	1	2		1	1							
INDUSTRY	1	2	2	2								
GOVERNMENT	1											
COMMUNITY COLLEGE OR HIGH SCHOOL												
FELLOWSHIP	2				3							
RESEARCH (OTHER THAN FELLOWSHIP)												
OTHER												
UNEMPLOYED												
UNKNOWN												
TOTAL	5	4	2	3	4							

(1) For those Ph.D.'s who were granted their degrees during the period, September 1 to August 31 of the year shown.

(2) The first employment obtained within six months of being granted the degree.

APR 26 '9''

Form 9.

A-72

UNIVERSITY SYSTEM TOTAL

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

EMPLOYMENT SURVEY OF PH.D.'s (1)

1971-72

EMPLOYMENT	IMMEDIATE (2)				
	ONTARIO	REST OF CANADA	HOME COUNTRY	OTHER	UNKNOWN
UNIVERSITY	1	1			
INDUSTRY					
GOVERNMENT		1			
COMMUNITY COLLEGE OR HIGH SCHOOL					
FELLOWSHIP	1			1	
RESEARCH (OTHER THAN FELLOWSHIP)	2				
OTHER					
UNEMPLOYED	1				
UNKNOWN					
TOTAL	5	2		1	

(1) For those Ph.D.'s who were granted their degrees during the period, September 1 to August 31 of the year shown.

(2) The first employment obtained within six months of being granted the degree.

APR 26 1973

Form 9.

A-73 UNIVERSITY SYSTEM TOTAL

METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

EMPLOYMENT SURVEY OF PH.D.'s (1)

1972-73

EMPLOYMENT	IMMEDIATE (2)				
	ONTARIO	REST OF CANADA	HOME COUNTRY	OTHER	UNKNOWN
UNIVERSITY					
INDUSTRY		/			
GOVERNMENT					
COMMUNITY COLLEGE OR HIGH SCHOOL					
FELLOWSHIP					
RESEARCH (OTHER THAN FELLOWSHIP)					
OTHER					
UNEMPLOYED					
UNKNOWN					
TOTAL		/			

(1) For those Ph.D.'s who were granted their degrees during the period, September 1 to October 31 of the year shown.

(2) The first employment obtained

APR 26 1973

Form 10, UNIVERSITY SYSTEM TOTAL

METALLURGICAL ENGINEERING DOCOTORAL PLANNING ASSESSMENT

TIME TO REACH DEGREE

1. For those students who took all their graduate work at the same university, with no time off between master's and doctoral work, but who may perhaps have had time off between later years of doctoral work, the total number of months from the time they started graduate school (make-up or qualifying year excluded) until they were granted their PH.D.

YEAR DEGREE GRANTED(1)	TOTAL ELAPSED TIME IN MONTHS							
	<36	36-43	44-47	48-51	52-59	60-71	72-84	>84
1972-73								
1971-72				1		1	2	1
1970-71	1		2	1	3	1	1	
1969-70			3	2	2	1		

2. For those students who took all their graduate work at the same university, with time off between master's and doctoral work (longer than nine months), but who may perhaps have had time off between later years of doctoral work, the total number of months from the time they started doctoral work until they were granted their PH.D.

YEAR DEGREE GRANTED(1)	TOTAL ELAPSED TIME IN MONTHS							
	<24	24-31	32-35	36-43	44-47	48-59	60-72	>72
1972-73								
1971-72								
1970-71								
1969-70								

(1) Degree granted during the period September 1 to August 31.

Form 10.

3. For those students who took their master's and doctoral work at different universities, with or without time off between the master's and doctoral work, the total number of months from the time they started doctoral work until they were granted their PH.D.

YEAR DEGREE GRANTED(1)	TOTAL ELAPSED TIME IN MONTHS							
	<24	24-31	32-35	36-43	44-47	48-59	60-72	>72
1972-73							1	
1971-72			1			2	1	
1970-71			1	1	1	4	1	1
1969-70					2			

(1) Degree granted during the period September 1 to August 31.

NOTE:

If a student had a master's degree from elsewhere, but nevertheless began his work at your university as a master's candidate, he is to be counted under categories 1 or 2 as appropriate, not under category 3.

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METALLURGICAL ENGINEERING DOCTORAL PLANNING ASSESSMENT

Post-Doctoral Man-Years Supervised

	Completed	In Progress	Number of C.V.'s
McMaster	75	4	10
Queen's	29	3	8
Toronto	23½	10	12
Western	4½	-	5
Windsor	13½	2	6
TOTAL	145½	19	41

APR 26 1971

CANADIAN ASSOCIATION OF GRADUATE SCHOOLS

PRESS RELEASE

For release: not before
4:00 p.m., Thursday,
December 14, 1972.

Employment of New Ph.D. Graduates
1971-72

There have been recent reports of current large scale unemployment of persons holding Ph.D. degrees, as well as forecasts suggesting future employment difficulties. These speculations are not substantiated by the actual experience of recent doctoral graduates.

In 1969, the Ontario Council on Graduate Studies collected information about the first employment of all those who obtained Ph.D.'s in Ontario in the preceding five years. This information has been obtained each year since for each new Ph.D. and last year and this year was extended to cover all of Canada.

Tables (attached) give the facts for the 1971-72 academic year and compare them with those for 1964-69 which was a period in which most new Ph.D.'s had a choice of several attractive job offers. The following summarizes the main points brought out in these tables.

In most universities the information was collected when the student handed in his thesis to the graduate school. At that time, ninety-six (96) percent of the Ph.D.'s had jobs. Of the remaining four percent (shown as "unemployed" in the tables), some will since have obtained employment, some were not actively seeking employment, and some are no doubt unemployed. This is essentially no change from last year. In 1970-71 there were 1446 Ph.D. graduates in Canada of whom 72 did not have jobs when the thesis was turned in; for 1971-72 the corresponding figures are 1446 and 53.

The unemployment rate of new Ph.D.'s is, therefore, less than four percent. Of course, this is much higher than the rate for the whole stock of Ph.D.'s in the population, and the four percent figure should not be compared with the six percent general unemployment rate in Canada, but rather with the twelve percent rate of the young people in the work force.

We are in a period of general employment difficulties. It is evident that in that framework, the doctoral employment picture is good. Even if it were not, it would be unwise to reduce new enrolment on the basis of the present business climate, since those now entering Ph.D. studies will not emerge for five years. Surely we are not to plan five years ahead on the assumption of continued business recession.

It is important to ask what kind of jobs these new Ph.D.'s have taken. In summary, the pattern has shifted only slightly from the boom years of the late sixties. Then, as now, the vast majority are doing worthwhile things appropriate to the investment made in their education by themselves and by the community.

The most noticeable shifts are a decrease in university teaching and in industrial employment. In 1964-69, forty-eight percent had university teaching posts as their first employment; this year the figure was thirty-eight percent. Industrial employment of Ph.D.'s has never been as important a factor as one might hope. In the sixties it accounted for thirteen percent of the graduates; last year this number fell to nine percent. Also stable is the fraction obtaining postdoctoral research fellowships. These postdoctoral research years are a normal part of the career pattern for those preparing for careers in university or government science. One quarter of the new Ph.D.'s are still following this route just as they did in the 60's. An interesting change is that whereas two-thirds of these fellowships were held outside Canada in the 60's, this year two-thirds were in Canada. In part, this tendency reflects the growing reputation of some departments in international science.

The drop in university teaching and in industrial employment is made up mostly by increases in the percentages engaged in a variety of occupations shown as "Other", as well as by the increase in "Unemployment". The "Other" category includes employment in business and finance, self-employment, consulting firms, high school teaching, school administration, and, no doubt, a variety of other jobs.

There are interesting figures concerning the geographical location of the new Ph.D.'s and how this varies with immigration status. Data is not available under this heading for all of Canada, but the Ontario figures are thought to be typical. Of the Canadian citizens, 85% are located in Canada, as are 65% of those with landed immigrant status. In contrast, 69% of those on student visas are located outside Canada. Contrary to what some have suggested, this shows a significant difference between those with landed immigrant status and those on student visas. Most landed immigrants intend to remain here, and the data show a high retention rate in Canada of potentially valuable citizens.

It is also apparent that the training in Canada of those on student visas is a contribution to our international role, for of the 69% who left Canada on graduation, 70% returned to their home countries. An equal number remained in

Canada, and very few went elsewhere. Thus, one of two things is happening to those here as foreign students. Either Canada is retaining the services of the people trained here or they are returned to their homeland. If they are from a developing country this represents an important contribution to world progress. If they are from an industrially developed area, they represent a part of the Canadian role in international scholarship. The total number of those on student visas was eleven percent of those graduating. This is an adequate but minimal level of involvement for a country like Canada on the international university scene. It may be noted that in 1970-71 the total number of Ph.D. degrees awarded in Canada to persons of all nationalities was about 1400; in the fiscal year 1971, in United States universities alone, 528 Canadians received Ph.D.'s and fifty-five percent of these returned immediately to Canada.

There may be further shifts in doctoral employment areas over the next year or two. There may be a larger number of people working in less traditional fields. We regard this as desirable, but we also consider that there are unlikely to be dramatic permanent shifts in employment. The graduate school enrolments have not grown for two years, indeed, in some fields there are indications that insufficient students are now entering to provide the needs of society five years hence.

TABLE 1.1

IMMEDIATE POST-GRADUATION EMPLOYMENT OF CANADIAN Ph.D.'s

ALL DIVISIONS

	CANADA#		ONTARIO		CANADA#		ONTARIO					
	1971-72		1971-72		1970-71		1970-71		1969-70		1964-69*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
OCCUPATION												
UNIVERSITY TEACHING												
In Canada	360	25	211	27	380	29	205	30	183	30	489	32
Elsewhere	162	11	88	11	144	11	85	12	74	12	248	16
Unknown	29	2										
Total	551	38	299	38	524	40	290	42	257	42	737	48
COMMUNITY COLLEGE+												
In Canada	48	3	19	2								
Elsewhere	4		2		+		+		+			
Unknown											30	2
Total	52	4	21	3							30	2
INDUSTRY												
In Canada	94	7	54	7	73	6	37	5	40	7	112	7
Elsewhere	29	2	18	2	42	3	25	4	18	3	79	5
Unknown	2											
Total	125	9	72	9	115	9	62	9	58	10	191	13
RESEARCH FELLOWSHIP												
In Canada	259	18	138	17	225	17	117	17	83	14	99	7
Elsewhere	130	9	80	10	151	11	73	10	86	14	272	18
Unknown	5											
Total	394	27	218	27	376	28	190	27	169	28	371	25
PRIVATE RESEARCH INSTITUTE												
In Canada	36	3	18	2	11	1	5	1	17	3	14	1
Elsewhere	16	1	7	1	14	1	9	1	11	2	12	1
Unknown												
Total	52	4	25	3	25	2	14	2	28	5	26	2
GOVERNMENT												
In Canada	87	6	37	5	99	7	49	7	41	7	108	7
Elsewhere	21	2	11	1	22	2	7	1	20	3	28	2
Unknown	5											
Total	113	8	48	6	121	9	56	8	61	10	136	9
UNEMPLOYED												
In Canada	41	3	33	4	64	4	35	5	10	2	1	
Elsewhere	1				8	1	4	1	5	1	5	
Unknown	11	1	3									
Total	53	4	36	5	72	5	39	6	15	2	6	
OTHER												
In Canada	91	6	67	8	63	5	38	5	12	2		
Elsewhere	13	1	6	1	18	1	9	1	6	1		
Unknown	2		1								20	1
Total	106	7	74	9	81	6	47	7	18	3	20	1
TOTAL	1446		793		1314		698		606		1517	
UNKNOWN@												
In Canada	11		10									
Elsewhere	14		6									
Unknown	116				29		10		18		289	
Total	141		16		29		10		18		289	

Excluding Laval.

* Includes "Other" disciplines as well as the four designated.

+ This category was not broken out from "Other" in 1969-70 and 1970-71.

@ It should be noted that 101 of the 116 "Unknown, unknown" are from non-returns in McGill's survey.

November 30, 1972

TABLE 1.2 A-82

IMMEDIATE POST-GRADUATION EMPLOYMENT OF CANADIAN Ph.D.'s

HUMANITIES (DIVISION A)

	CANADA		ONTARIO		CANADA		ONTARIO					
	1971-72		1971-72		1970-71		1970-71		1969-70		1964-69*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
OCCUPATION												
UNIVERSITY TEACHING												
In Canada	101	56	76	62	109	67	75	67	66	73	124	69
Elsewhere	34	19	27	22	25	15	19	17	13	14	45	25
Unknown	12	7										
Total	147	82	103	84	134	83	94	84	79	88	169	94
COMMUNITY COLLEGE												
In Canada	9	5	4	3								
Elsewhere												
Unknown											3	2
Total	9	5	4	3							3	2
INDUSTRY												
In Canada											1	1
Elsewhere												
Unknown												
Total											1	1
RESEARCH FELLOWSHIP												
In Canada	1		1	1	4	2	2	2				
Elsewhere	1		1	1							2	1
Unknown	1											
Total	3	2	2	2	4	2	2	2			2	1
PRIVATE RESEARCH INSTITUTE												
In Canada	2	1	1	1	2	1	1	1				
Elsewhere					1	1					1	1
Unknown												
Total	2	1	1	1	3	2	1	1			1	1
GOVERNMENT												
In Canada	2	1	2	2	3	2	2	2	1	1	2	1
Elsewhere									2	2		
Unknown	1	1										
Total	3	2	2	2	3	2	2	2	3	3	2	1
UNEMPLOYED												
In Canada	5	3	4	3	9	6	5	4	3	3	1	1
Elsewhere	1				1	1			2	2		
Unknown	1											
Total	7	4	4	3	10	7	5	4	5	6	1	1
OTHER												
In Canada	7	4	6	5	8	5	8	7	3	3		
Elsewhere												
Unknown	1		1	1							1	1
Total	8	4	7	6	8	5	8	7	3	3	1	1
TOTAL	179		123		162		112		90		180	—
UNKNOWN												
In Canada	1											
Elsewhere	1		1									
Unknown	19				5		2		3		53	
Total	21		1		5		2		3		53	

* Includes other disciplines not already designated

November 30, 1972

TABLE 1.3

IMMEDIATE POST-GRADUATION EMPLOYMENT OF CANADIAN Ph.D.'s

SOCIAL SCIENCES (DIVISION B)

	CANADA 1971-72		ONTARIO 1971-72		CANADA 1970-71		ONTARIO 1970-71		ONTARIO 1969-70		ONTARIO 1964-69*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
OCCUPATION												
UNIVERSITY TEACHING												
In Canada	119	45	58	43	106	54	53	43	44	42	118	54
Elsewhere	38	15	20	15	30	15	23	19	22	21	36	16
Unknown	2	1										
Total	159	61	78	57	136	69	76	62	66	63	154	70
COMMUNITY COLLEGE												
In Canada	16	6	7	5								
Elsewhere	1											
Unknown											9	4
Total	17	6	7	5							9	4
INDUSTRY												
In Canada	3	1			2	1	2	2	2	2	10	5
Elsewhere	1		1	1	1	1					8	3
Unknown												
Total	4	1	1	1	3	2	2	2	2	2	18	8
RESEARCH FELLOWSHIP												
In Canada	6	2	4	3	9	4	7	6	4	4	3	1
Elsewhere	5	2	5	4	5	2	5	4	3	3	5	2
Unknown												
Total	11	4	9	7	14	6	12	10	7	7	8	4
PRIVATE RESEARCH INSTITUTE												
In Canada	8	3	4	3	3	2	1	1	7	7	2	1
Elsewhere	2	1	2	1	2	1	1	1				
Unknown												
Total	10	4	6	4	5	3	2	2	7	7	2	1
GOVERNMENT												
In Canada	16	6	7	5	16	8	14	11	11	10	24	11
Elsewhere	2	1			1	1	1	1	4	4	1	
Unknown	1											
Total	19	7	7	5	17	9	15	12	15	14	25	11
UNEMPLOYED												
In Canada	5	2	4	3	4	2	2	2	3	3		
Elsewhere											1	
Unknown	2	1	1	1								
Total	7	3	5	4	4	2	2	2	3	3	1	
OTHER												
In Canada	33	13	23	17	15	8	12	10	2	2		
Elsewhere	1				3	2	2	1	3	3		
Unknown	1										4	2
Total	35	13	23	17	18	10	14	11	5	5	4	2
TOTAL	262		136		197		123		105		221	
UNKNOWN												
In Canada	1		1									
Elsewhere	1											
Unknown	32				8		4		5		39	
Total	34		1		8		4		5		39	

* Includes other disciplines not already designated

November 30, 1972

TABLE 1.4 A-84

IMMEDIATE POST-GRADUATION EMPLOYMENT OF CANADIAN Ph.D.'s

PHYSICAL AND APPLIED SCIENCES (DIVISION C)

	CANADA 1971-72		ONTARIO 1971-72		CANADA 1970-71		ONTARIO 1970-71		ONTARIO 1969-70		ONTARIO 1964-69*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
OCCUPATION												
UNIVERSITY TEACHING												
In Canada	97	14	59	16	108	16	54	16	53	17	186	23
Elsewhere	57	9	24	6	67	10	36	11	24	8	115	14
Unknown	9	1										
Total	163	24	83	22	175	27	90	27	77	25	301	37
COMMUNITY COLLEGE												
In Canada	18	3	8	2								
Elsewhere	2		1									
Unknown											9	1
Total	20	3	9	2							9	1
INDUSTRY												
In Canada	80	12	51	14	58	9	32	10	36	12	95	12
Elsewhere	26	4	17	5	39	6	23	7	18	6	68	8
Unknown	2											
Total	108	16	68	18	97	15	55	16	54	18	163	20
RESEARCH FELLOWSHIP												
In Canada	179	27	95	26	149	23	83	25	59	19	67	8
Elsewhere	67	10	42	11	83	13	35	10	59	19	191	23
Unknown	3											
Total	249	37	137	37	232	35	118	35	118	38	258	32
PRIVATE RESEARCH INSTITUTE												
In Canada	17	3	8	2	3		1		7	2	4	
Elsewhere	3		1		5	1	4	1	10	3	4	
Unknown												
Total	20	3	9	2	8	1	5	1	17	6	.8	1
GOVERNMENT												
In Canada	42	6	18	5	49	7	21	6	22	7	51	6
Elsewhere	9	1	7	2	14	2	3	1	9	3	21	3
Unknown	3											
Total	54	8	25	7	63	10	24	7	31	10	72	9
UNEMPLOYED												
In Canada	23	3	19	5	41	6	23	7	3	1		
Elsewhere					4	1	3	1	1		1	
Unknown	6	1	2	1								
Total	29	4	21	6	45	7	26	8	4	1	1	
OTHER												
In Canada	22	3	14	4	28	4	12	4	4	1		
Elsewhere	4	1	3	1	11	2	5	1	2	1	7	1
Unknown												
Total	26	4	17	5	39	6	17	5	6	2	7	1
TOTAL	669		369		659		335		307		819	
UNKNOWN												
In Canada	9		9									
Elsewhere	8		3									
Unknown	33				13		4		9		140	
Total	50		12		13		4		9		140	

* Includes other disciplines not already designated

November 30, 1972

TABLE 1.5

IMMEDIATE POST-GRADUATION EMPLOYMENT OF CANADIAN Ph.D.'s

LIFE SCIENCES (DIVISION D)

	CANADA 1971-72		ONTARIO 1971-72		CANADA 1970-71		ONTARIO					
							1970-71		1969-70		1964-69*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
OCCUPATION												
UNIVERSITY TEACHING												
In Canada	43	13	18	11	57	19	23	18	16	17	50	18
Elsewhere	33	10	17	10	22	7	7	5	11	11	44	16
Unknown	6	2										
Total	82	24	35	21	79	27	30	23	27	28	94	34
COMMUNITY COLLEGE												
In Canada	5	1										
Elsewhere	1		1	1								
Unknown											6	2
Total	6	2	1	1							6	2
INDUSTRY												
In Canada	11	3	3	2	13	4	3	2	2	2	6	2
Elsewhere	2	1			2	1	2	2			3	1
Unknown												
Total	13	4	3	2	15	5	5	4	2	2	9	3
RESEARCH FELLOWSHIP												
In Canada	73	22	38	23	63	21	25	20	20	21	29	11
Elsewhere	57	17	32	19	63	21	33	26	24	25	74	27
Unknown	1											
Total	131	39	70	42	126	43	58	45	44	46	103	38
PRIVATE RESEARCH INSTITUTE												
In Canada	9	3	5	3	3	1	2	2	3	3	8	3.
Elsewhere	11	3	4	2	6	2	4	3	1	1	7	2
Unknown												
Total	20	6	9	5	9	3	6	5	4	4	15	5
GOVERNMENT												
In Canada	27	8	10	6	31	10	12	9	7	7	30	11
Elsewhere	10	3	4	2	7	2	3	2	5	5	6	2
Unknown												
Total	37	11	14	8	38	13	15	12	12	12	36	13
UNEMPLOYED												
In Canada	8	2	6	4	10	3	5	4	1	1		
Elsewhere					3	1	1	1	2	2	3	1
Unknown	2	1										
Total	10	3	6	4	13	4	6	5	3	3	3	1
OTHER												
In Canada	29	9	24	14	12	4	6	5	3	3		
Elsewhere	8	2	3	2	4	1	2	2	1	1		
Unknown											8	3
Total	37	11	27	16	16	5	8	6	4	4	8	3
TOTAL	336		165		296		128		96		274	
UNKNOWN												
In Canada												
Elsewhere	4		2									
Unknown	32				3				1		37	
Total	36		2		3				1		37	

* Includes other disciplines not already designated

November 30, 1972

TABLE 2

IMMEDIATE POST-GRADUATION EMPLOYMENT OF ONTARIO Ph.D.'s

LOCATION AND TYPE OF EMPLOYMENT BY CITIZENSHIP

	CANADIAN						LANDED IMMIGRANT								STUDENT VISA					
	Ontario		Rest of Canada		Elsewhere		Ontario		Rest of Canada		Elsewhere		Unknown		Ontario		Rest of Canada		Elsewhere	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
UNIVERSITY	100	22.3	72	16.1	12	2.7	25	9.2	10	3.7	38	13.9			2	2.3	2	2.3	38	43.2
INDUSTRY	25	5.6	10	2.2			11	4.0	7	2.6	11	4.0					1	1.1	7	8.0
GOVERNMENT	23	5.1	5	1.1	4	0.9	6	2.2	2	0.7	3	1.1			1	1.1			4	4.5
COMMUNITY COLLEGE	10	2.2	3	0.7			5	1.8	1	0.4	2	0.7								
FELLOWSHIP	49	10.9	18	4.0	44	9.8	49	17.9	8	2.9	27	9.9			10	11.4	4	4.5	9	10.2
PRIVATE RESEARCH	8	1.8	2	0.4	2	0.4	8	2.9			5	1.8	1	0.4						
OTHER	33	7.4	9	2.0	3	0.7	22	8.1			2	0.7	3	1.1	3	3.4			1	1.1
UNEMPLOYED	12	2.7	2	0.4			15	5.5	1	0.4					3	3.4				
UNKNOWN	2	0.4					7	2.6			4	1.5			1	1.1			2	2.3
TOTAL	262	58.5	121	27.0	65	14.5	148	54.2	29	10.6	92	33.7	4	1.5	20	22.7	7	8.0	61	69.3
	← 448 (100%) →						← 273 (100%) →								← 88 (100%) →					

November 30, 1972

TABLE 3

IMMEDIATE POST-GRADUATION EMPLOYMENT OF ONTARIO Ph.D.'s

SYSTEMS TOTAL FOR ALL DIVISIONS

	ONTARIO			REST OF CANADA			HOME COUNTRY		OTHER			UNKNOWN			U of T		
															HOME/OTHER		
	Can.	LI	SV	Can.	LI	SV	LI	SV	Can.	LI	SV	Can.	LI	SV	Can.	LI	SV
UNIVERSITY TEACHING	100	25	2	72	10	2	9	16	8	19	5				4	10	17
INDUSTRY	25	11		10	7	1	4	5		5	2					2	
GOVERNMENT	23	6	1	5	2		2	4	1						3	1	
COMMUNITY COLLEGE	10	5		3	1		2										
FELLOWSHIP	49	49	10	18	8	4	3	1	19	15	4				25	9	3
RESEARCH	8	8		2			2		2	2						1	
OTHER	33	22	3	9				1	2				1		1	2	
UNEMPLOYED	12	15	3	2	1								3				
UNKNOWN	2	7	1				3									1	2
TOTAL	262	148	20	121	29	7	25	27	32	41	11		4		33	26	22

NOTE: Can. - Canadian
LI - Landed Immigrant
SV - Student Visa

November 30, 1972

APPENDIX B

DISCIPLINE GROUP RESPONSE

FORMAL STATEMENT
by the
METALLURGICAL AND MATERIALS ENGINEERING DISCIPLINE GROUP
on the
REPORT OF THE ACAP CONSULTANTS

C. B. Alcock

G. R. Piercy

P. Niessen

W. B. Mackay

J. D. Brown

W. V. Youdelis (Chairman)

FORMAL STATEMENT
by the
METALLURGICAL AND MATERIALS ENGINEERING DISCIPLINE GROUP
on the
REPORT OF THE ACAP CONSULTANTS

GENERAL

The following is a commentary on the apparent philosophy or criteria used by the consultants in making their recommendations contained in the report, and serves as the Discipline Group's exposition of its own philosophy or criteria on which the comments, criticisms, and recommendations in this statement are based.

(1) Interpretation of "Metallurgical Engineering"

In the report metallurgical engineering is subdivided into three principal parts: extractive (chemical) metallurgy, materials science, and materials engineering. The differentiation of the latter two may be regarded as discipline-orientated, and this leads, in the opinion of the Discipline Group, to undue emphasis in the report on broadness at the expense of depth in PhD programmes. Thus the report recommends that the student should have some exposure, mostly through formal courses, to all the different fields of materials, as well as obtaining a good background in applied physics and applied chemistry. It is the consensus of the Discipline Group that the opportunities for this type of PhD graduate in Canada are limited. The present state of industrial development in Canada is still largely directed to materials producing rather than materials using, and the need is largely for graduates with a more specialized or career-orientated education, e.g. extractive metallurgy, physical metallurgy, ceramics, polymers, etc. The more broadly educated materials engineer or materials scientist, as envisaged in the report, may find more need for his services in the materials using industries; however, even here a considerable degree of specialization will be needed.

It is the point-of-view of the Discipline Group that a good materials engineering programme must have some materials science, and the reverse is also desireable. Moreover, there is a wide range of subject matter and research which cannot be classed as either science or engineering, and thus the differentiation between the two as developed in the report can only be used in a most general way. It is impracticable to attempt any strict classification of a specific research project or course according to the science or engineering content.

(2) The Supply and Demand for Manpower

The report makes a clear and well substantiated refutation of future PhD manpower supply and demand as projected in the Ring of Iron and the

Canadian Engineering Manpower Council Report. It recommends that the projected demand figures in the above reports should be at least doubled. It also concludes that Canadian industry has a strong prejudice against employing Canadian PhD graduates of Asian origin, and recommends intensifying efforts to recruit PhD students from Canadian undergraduate programmes. Towards this end the report recommends substantially increasing payment to graduate students. Based on the collective experience of its members, the Discipline Group fully agrees with the report's analysis of future manpower requirements in metallurgy and materials, and has already stated its similar experience regarding the placement of PhD graduates with a non-western background in industry (see Discipline Group's Report on Doctoral Studies in Metallurgical and Materials Engineering). The Discipline Group strongly endorses the recommendation that the efforts to recruit Canadian students be intensified, and that payment to graduate students be substantially increased.

The report's recommendation for increasing the total PhD student population is metallurgy and materials is qualified by the statement that "most of the necessary substantial increase in the output of PhD's should be from departments with comprehensive programmes in materials engineering or materials science or both". While it is to be expected that most of the increase will come from the larger departments with their correspondingly larger student populations, the Discipline Group recommends that the smaller departments with established PhD programmes continue to make their proportionate contribution to the total output of PhD's. This recommendation is made in explicit recognition of the unique and significant role of the smaller school in graduate education and research in Canada, a fact that has been largely ignored in the report.

(3) The Quality of the Educational Experience

The report compares the American system with the British system for graduate education and comes out clearly in support of the former. In the American system considerable emphasis is placed on formal courses, while in the British system the graduate programme is centered around the thesis. It is argued that a good PhD programme requires a broad range of formal courses, which can be adequately provided only in large departments, and many of the recommendations in the report clearly reflect this philosophy. Significantly, however, the report does admit that "no obvious correlation exists between the performances and achievements of PhD graduates and the system in which they were educated".

It is the consensus of the Discipline Group that the Canadian system of graduate education, which falls somewhere between the American and British systems, strikes a better balance between course load and thesis emphasis. The Canadian PhD programme is more specialized and career-oriented, and so requires fewer formal courses when compared to the more discipline-orientated materials programme as envisaged in the report. These can for the most part be adequately provided in smaller departments, particularly if there is some integration or collaboration with other departments in the faculty (e.g. physical metallurgy with mechanical engineering and extractive metallurgy with chemical engineering).

The report addresses itself to the question of the effect of a PhD programme on recruitment of staff to teach undergraduate programmes and admits, "that most professors with a strong interest in research are unlikely to be content to work in a predominantly undergraduate environment". It is the view of the Discipline Group that failure to recruit and retain a good proportion of faculty members with strong research interests will ultimately have a negative effect on the undergraduate programme, for it is through the correct combination of teaching, research, and professional talent that vigor and progress will be best assured. Finally, the assessment and planning of graduate programmes cannot be entirely rational or realistic if done in isolation to existing undergraduate programmes and priorities. In this regard it is questionable if the proscribed terms of reference for the assessment, i.e. limitation to doctoral programmes only, have not predetermined the conclusions, and that the report's recommendations may have been substantially different if the terms of reference had allowed a broader and more integrated perspective.

GENERAL RECOMMENDATIONS

The report gives three general recommendations relating to doctoral programmes in the province of Ontario, and two recommendations relating to supply and demand of PhD's. Taking cognizance of the agreed need for increasing the PhD output in metallurgy and materials, and that this increase in output should be effected by all departments with established PhD programmes in Ontario participating, the Discipline Group recommends altering or qualifying the report's general recommendations on page A-i and A-ii to read as follows:

Recommendations Relating to Doctoral Programmes in Ontario:

(1) The existing programmes in extractive (chemical) metallurgy be strengthened, and at least one be maintained at a level of international stature.

(2) The existing programmes in materials science be strengthened, and at least one be maintained at a level of international stature.

(3a) Wherever programmes in metallurgical, ceramic, or polymer engineering exist they be combined and augmented to develop strong programmes in materials engineering. It is not essential that the integrated programmes be under the administrative control of one department.

(3b) The proportion of the effort in materials engineering devoted to ceramics and glasses be increased.

(3c) At least one materials engineering department or group develop a strong programme in polymeric materials integrated with the general materials engineering programme.

Recommendations Relating to Manpower:

(1) The figures for anticipated demand in 1974-75 for PhD's in Ontario in "mining, metallurgy and materials" be at least double those given in Table 58 of the report of the Canadian Engineering Manpower Council, July 1973, and the targets for the total PhD student population be adjusted accordingly.

(2) Efforts to recruit a larger proportion of the PhD students from the graduates of Canadian undergraduate programmes should be continued and intensified. The stipends paid to Canadian graduate students are inadequate to attract a sufficient number and should be increased substantially.

RECOMMENDATIONS FOR INDIVIDUAL UNIVERSITIES

The Discipline Group does not consider it necessary or appropriate to comment on the report's specific recommendations for each University. The responses to the recommendations are given in each institution's report, and insofar as they are consistent with the philosophy and general recommendations of this report, they have the full endorsement of the Discipline Group.

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APPENDIX C

UNIVERSITY COMMENTS

Comments appear from Carleton, McMaster, Queen's, Toronto, Waterloo, Western Ontario and Windsor. (Carleton has no representative on the Discipline Group.)

CARLETON UNIVERSITY

RESPONSE TO FOUR ACAP ASSESSMENTS ON ENGINEERING

Introduction

Carleton takes the view that groups of disciplines should be evaluated before a clear picture of the situation within a single discipline can be obtained. Reports on any one component considered in isolation could lead to an erroneous judgement and unwise and precipitate action. Three consultants' final assessment reports have now been received for engineering disciplines in which Carleton is actively involved: Civil Engineering, Electrical Engineering, and Mechanical and Aeronautical Engineering. A fourth report deals with Metallurgical and Materials Engineering, of less direct concern to Carleton, while a fifth report, not yet received, will deal with Chemical Engineering, a discipline not represented at Carleton.

This response will address itself to the four reports which have been received and examined to date. We may wish to add further comments when the fifth report has been studied.

We sense a good deal of unanimity on a number of fundamental questions among the fifteen consultants involved in the four reports so far received, a communality of viewpoint which we share and endorse. We believe that Engineering has been most fortunate in having the assessments carried out by a group of consultants whose international stature, valued judgement and perspective give authority and credibility to their studies and reports. In general then we accept their findings and subscribe to their recommendations with only a few exceptions to be noted later.

In this response we shall deal first with those matters which we believe to be basic and general in nature and leave until the end our views on specific points raised in individual reports.

Matters of a Fundamental or General Nature

1) Control of Student Numbers:

The four reports are unanimous in their opinion that previous estimates of the demand for engineers with doctoral degrees, notably those in the Lapp Report of 1970 and the report for CEMC of 1973, have erred seriously on the low side. They point out that there is no evidence of difficulty in obtaining jobs by students close to graduation, nor do they foresee difficulties in the future except for those which normally occur in highly specialized areas.

The consultants reject the notion of quotas applied to departments to control student numbers, in part because the demand seems likely to exceed the supply than the reverse, making quotas unnecessary, but in the main because they feel that other means of control are to be preferred. The report on Electrical Engineering puts it this way: "The number of doctorates granted in electrical engineering (should) be determined by:

(i) availability of qualified students
(ii) maintenance of adequate standards by the universities, and
(iii) the existing capacity (staff and facilities) of the universities for giving adequate training." The Mechanical consultants refer to emerging natural controls and go on to say: "We would wish the resources of the present system, which are predicated principally on undergraduate requirements, the market demands, the quality of the programme and the good judgement of the departments to determine the total number within the system."

Carleton subscribes fully to these views. We believe that rather than through centrally imposed quotas or limitations the universities individually should control numbers by restricting admission to students showing high promise and by maintaining adquate standards. The latter together with the market demand will provide an adequate control. We would be prepared to support the development and adoption of an evaluation scheme, such as the scholastic index used at Carleton, which can be applied across all disciplines and which could be used in the monitoring of admission standards which we believe should be a matter between a university and OCGS. We believe, however, that the interpretation of these standards for individual student cases should be left to the informed judgement of the university concerned.

2) Quality of Existing Programmes, Suggestions for Change:

From their comments on the quality of the Ph.D. programmes for the system generally, it is clear that the consultants believe it to be quite acceptable. The Civil consultants point out that "the system provides a good quality coverage of the field and specialties without undue overlap on a regional basis." Comments on individual universities draw attention to departures from the norm in both directions.

A common theme running through the reports is the need for greater flexibility in the future. The Metallurgical and Materials consultants state it this way: "As Canadian industry becomes more sophisticated and has to rely on more advanced technologies, it will have to learn how to fully utilize the talents and skills of Ph.D. graduates and the universities will have to learn how to develop Ph.D. programmes which produce imaginative engineers capable of responding to these new opportunities." These consultants also recommend that programmes be so designed as to permit graduates from other specialties to change specialties as they commence Ph.D. work.

The consultants also show a degree of consistency regarding the need to shift the emphasis in Ph.D. programmes to meet the situation of the seventies. The Electrical consultants state it this way: "The education of Ph.D. students in areas of national need is a more efficient use of resources than is a random choice of fields followed by a period of retraining." In relating it to their field, the Civil consultants state that there should be "less stress on traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation." The Mechanical consultants recommend a greater emphasis on production engineering and design.

Close contact between universities and industry is felt to be important by all the consultants and individual universities have been singled out for commendation where this contact is regarded as exemplary while others have been asked to improve in this respect.

Once again Carleton accepts the findings of the consultants on the quality of the existing programmes and their views on the nature of Ph.D. programmes required for the immediate future. We feel that we have already made considerable progress toward achieving the desirable objectives set out by the consultants and that we have received adequate recognition for this in their reports.

3) Critical Size:

The Engineering consultants are far less concerned about the concept of critical size than the consultants who carried out some of the earlier planning assessments, and show as much concern for the disadvantages of "bigness" as of "smallness." The Engineering consultants place their primary emphasis on the quality of the student and of the faculty rather than on size, a view which we heartily endorse.

The Mechanical consultants take the strongest stand against the notion of critical size. While admitting the advantages enjoyed by a large group, they go on to express their view that "a drawback to the large group is the difficulty of adapting to change" and further that "the groups in the smaller departments often displayed an original point of view and a willingness to adapt to change that was not apparent in the larger and longer established departments." They found more cross linkages between departments and a greater tendency to establish outside contacts with government and industry in the smaller faculties. They conclude: "In our view no creative group, and no capable individual within such a group should be denied support because it is small." The Civil consultants echo these views: "Size is not a sufficient criterion for judging whether a school can offer a Ph.D. programme" and also "there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as a large school."

The Electrical and Metallurgical and Materials consultants are not as definite on the matter of critical size as the Civil and Mechanical consultants. The Electrical consultants felt that a desirable size for a department fell in the range from 10 to 20 faculty with from 10 to 20 students enrolled but expressed the view that "high standards of excellence with emphasis on quality rather than quantity will pay off in the long run." The Metallurgical and Materials consultants draw attention to the contrast between the British approach to Ph.D. education centered around the thesis and requiring only one good faculty member and the American view that a department needs to be sufficiently large to provide a proper range of courses because of the importance given to course work in the American approach. The consultants themselves took the position that students should be taught by members of the basic science departments as well as by Engineering faculty members and that the critical size of the core depends a great deal on the strengths in related disciplines. The latter factor seems to have been ignored by some of the consultants who assessed the non-Engineering disciplines.

As indicated above, Carleton is fully in agreement with the position on critical size taken by the Engineering consultants and does not support the views of the Chemistry or Economics consultants nor ACAP's views on this matter.

4) Proportion of Foreign Students:

All four of the reports under review make reference to the enrolment of foreign students in the graduate programmes at Ontario Universities.

The Electrical consultants noted that the percentage of doctoral students with first degrees from Canadian universities was consistently in the range from 47 to 51 over the past five years. They believe an ideal mix should involve students with a variety of backgrounds coming from various universities and should include some students from foreign countries. The latter they feel should be in the minority and they suggest 25% as an appropriate proportion. The Civil consultants expressed concern also at the low percentage of full-time Ph.D. students who had obtained their first degree in Canada but remarked also that the percentage was much higher for part-time students and suggested that part-time studies should be encouraged.

The Mechanical consultants, while noting a similar proportion of non-Canadian first degree students to those mentioned above concluded that we cannot count on Canadian undergraduate schools to provide candidates in sufficient numbers and that we must continue to rely on students from abroad. The latter would likely decrease in number in the future due to recent policy changes with respect to immigration and financial support for students without landed immigrant status. They suggest that support for such students should come from appropriate federal agencies such as CIDA.

The Metallurgical and Materials consultants find that "Canadian industry unable to fill its vacancies with Canadian graduates of Canadian origin has preferred to import graduates from British or Australian origin rather than employ Canadians of Asian origin." They recommend an intensification of efforts to recruit a larger proportion of Ph.D. students from the graduates of Canadian universities.

Carleton is in agreement with the consultants concerning the desirability of having a mix of students from different universities in Canada and from foreign countries and in having a reasonable balance between Canadian and non-Canadian first degree holders. The problem of foreign students is usually expressed as one of controlling their number. We believe that the recent immigration and financial restrictions imposed on this group is likely to overshoot the mark and the problem in the future may well be one of too few rather than too many foreign students. A more serious problem is that of too few graduates of Canadian schools embarking on Ph.D. work.

Comments on Some Specific Matters

In this section we wish to deal with some specific issues raised in individual assessment reports.

1) Civil Engineering Doctoral Planning Assessment:

The references to Carleton University throughout this report are generally favourable and on the whole we like their conclusions and recommendations. There are, however, one or two points we wish to question.

In Recommendation 3 the consultants suggest "there is a case for more consistent requirement of acceptance for Ph.D. students between universities." We are uncertain as to the meaning of this since it is not discussed in the body of the report. We have expressed the view earlier that there should be a system, such as Carleton's scholastic index, for evaluating students across all disciplines, and that OCGS might monitor standards of admission generally. We do not see the need for an external person on acceptance committees but continue to support the position that there should be external examiners on thesis committees.

We cannot accept the proposal in Recommendation 5 concerning the collapsing of the Ph.D. B.I.U.'s into the undergraduate B.I.U.'s although we can support the objective. We believe that a major re-examination of the formula for providing operating funds to the universities is called for, not just minor adjustments to B.I.U. weightings.

We do not see the necessity for the further proliferation of degree designations which would result from the introduction of the Doctor of Engineering Degree included in Recommendation 12. We support fully the consultants' concept of a range of possibilities for a doctoral thesis, from the mathematical or theoretical at one end to the design or application-orientated at the other end, but we believe the requirements for the Ph.D. should be flexible enough to permit this as is the case at Carleton.

2) Report on Doctoral Programmes in Electrical Engineering in Ontario Universities.

For the purposes of assessment and reporting, the consultants have combined Carleton's departments of Electronics and Materials Engineering and Systems Engineering under the discipline title of 'Electrical Engineering.' Their comments, conclusions and recommendations apply uniformly to our two departments. We regard this report as a highly competent and thorough piece of work. The analysis in the earlier sections prior to the evaluation of departments gives to the whole a degree of credibility that is probably unique in such reports.

Carleton University has received a uniformly favourable assessment in Electrical Engineering. The Ph.D. programmes in both departments are considered to be "strong.". The interaction of Carleton with laboratories and firms in the Ottawa area is described as a "model" while our programmes are praised as having "unusually high contemporary relevance."

We intend to pursue our proposed five-year plan for the graduate programme in Electrical Engineering; we believe that our present organization into the two departments of Electronics and Materials Engineering and Systems Engineering is the most appropriate and effective for our purposes and intend to maintain this organization.

We have noted the general recommendation that only students showing high promise for graduate work should be accepted into the Ph.D. programme. We endorse this recommendation.

We plan to aim for the small growth in graduate student numbers proposed in the five-year plan, but note that in the consultants' view this growth is modest. We shall allow ourselves to be responsive to the applications which we receive from well-qualified students. We expect that our growth will be limited to a natural and non-excessive rate by the limited availability of good applicants.

We believe that it is possible to increase the scale and effectiveness of our associations with laboratories and firms in the Ottawa area and shall endeavour to exploit further such interactions.

The recommendation that greater use be made of graduate courses given at the University of Ottawa is accepted. The establishment of a close working relationship over the last two-year period has made the sharing of course offerings and facilities a natural outcome which it is intended to exploit.

We accept the report of the ACAP consultants without reservation. We consider the assessment to have been fairly and thoroughly done and believe that the report as a whole will be of considerable benefit to the Electrical Engineering profession in Ontario and Canada.

3) Report of the Mechanical Engineering Consultants:

We accept the ACAP consultants' report on Mechanical (and Aeronautical) Engineering without reservation. We consider it to be a valuable, authoritative, well reasoned document. The report is thoroughly credible because of the competence and international stature of the consultant team and the excellent overview they provide.

We accept the consultants' argument that, because "the developing market could easily absorb double the rate of output (presently about 30 Ph.D.'s/year in Ontario) during the next five years" and because of the serious undersupply of qualified candidates, assigned quotas for the Ontario system would be meaningless.

We agree that adequate capacity and quality exists within the department and that decisions about specific research areas should be made within the individual universities. We accept the criticism that excessive effort has been devoted to "traditional and classical areas of research" and that our efforts should continue to be re-directed towards research more pertinent to the practice of Mechanical and Aeronautical Engineering. We agree that the relevance of the research work would be enhanced if support were made more dependent on contracts from high technology industry and appropriate federal government departments.

We intend to pursue our proposed five-year plan and strengthen our contacts with industrial and government laboratories. We will explore the possibility of establishing an industrial research institute (or an office of industrial research) since these institutes are noted as having a highly beneficial effect on the research of the faculty and graduate students.

We applaud the recommendation that a good Ph.D. programme should provide breadth by means of well balanced course work and depth by means of a thesis involving substantial research on a specific and topical engineering problem. Doctoral graduates from such a balanced educational programme will be able to move into industry and tackle problem solving on a broad front.

Conclusion

We hope that it will be clear from the foregoing that we find the reports generally quite acceptable and can endorse all their major conclusions and recommendations. We regard the specific points on which we disagree with the consultants to be minor in comparison to the aggregate of the issues on which we agree.

G. R. Love
November 12, 1973

RESPONSE OF McMASTER UNIVERSITY

TO

REPORT ON DOCTORAL STUDIES IN METALLURGICAL AND MATERIALS ENGINEERING IN THE PROVINCE OF ONTARIO

This report deals most effectively indeed with fields of studies that have strong multidisciplinary overtones, and that involve both Science and Engineering Faculties and Departments. It does this by providing an interpretation of "Metallurgical Engineering" that is well founded in both historic and recent developments, and gives a convincing overview that lends conviction to the trends foreseen and to the needs envisioned. By adding to this a thorough quality assessment and a careful approach to the estimation of manpower requirements, the consultants have produced a most commendable document. It is system-oriented, stating direct challenges towards increasing cooperative efforts. Overall, therefore, we find the content and the recommendations most useful for planning and development purposes, and we are appreciative of the fairness of approach and the efforts devoted to it by the consultants.

The view of "Metallurgical Engineering" has been carefully delineated as encompassing extractive metallurgy, materials science, and materials engineering. This classification, like any classification of research and graduate instruction, into apparently separable elements, can create some misunderstanding and confusion. It can be academically dangerous if it becomes divisive rather than giving emphasis to the common elements and relationships. In our view, it can be claimed that the classes adopted in this report (extractive metallurgy, materials science and materials engineering) are well defined, but most appropriately so for highly-developed countries such as the U.S.A. in which most Ph.D. graduates are employed in the secondary industries that use materials. In Canada there are as yet relatively few secondary industries with a sufficiently complex technology to hire large numbers of Ph.D.'s. There is no question about the validity of the classification of extractive metallurgy, though we prefer the term chemical, or process, metallurgy as it more clearly can include chemical refining processes and corrosion, as well as the extracting of metal from ore. The other classes (materials science and materials engineering), while presented with a convincing rationale, should not in our view completely nor immediately displace the more traditional classes of physical metallurgy, ceramics and polymers. These are relevant, for example, in the case of a steel manufacturer who hires a Ph.D. graduate from the area of physical metallurgy, since he needs a person with knowledge, expertise and experience in metals predominantly and to a much lesser extent in polymers and ceramics. In fact, in this case, additional breadth would probably be more desirable in the mechanical engineering aspects of fabrication, machinability or wear than in polymers. Thus, a materials engineer, while perhaps more desirable for a materials user, is less desirable for a materials producer. Many departments, therefore, still operate Ph.D. programs in metallurgy without a broad materials emphasis because their graduates will always be needed by the metal producers -

representing a major sector of Canadian industry. However, the need of the material-user industries for Ph.D. graduates will be increasing faster than that of the producer industries, and these needs too must be met by our universities. We therefore do support strongly the strengthening of programs in materials science, and the establishment of at least one materials engineering program. At the same time, we would emphasize that in our view any good materials engineering program must include some materials science; and the reverse, of course, is desirable. Thus, an emphasis in one of these classes must not exclude some work also being done in the other.

A Ph.D. program, to the student, is primarily for personal education and for training and experience in solving complex problems: definition, analysis, and examination. The consultants, in their statement on extractive metallurgy, emphasize (page A-7) that the "need for scientific sophistication expected of a Ph.D. graduate (in extractive metallurgy) appears to be small". If this is translated as "sophisticated applied chemistry and applied physics", then any limiting to this concept by our existing schools in metallurgy and materials will fail, at least to some degree, to meet the needs of industries with problems to be solved by other techniques, and/or at a less sophisticated level. This may well have resulted in a too-restricted market for Ph.D. graduates. An example of this could be in the area of extractive metallurgy, where sorting out the complex requirements for raw product characterization and mineral beneficiation, within the constraints of energy requirements and economics, presents a formidable challenge, beyond that of "scientific sophistication". We therefore support the proposal which encourages additional breadth of Ph.D. programs in extractive metallurgy and physical metallurgy to include problem solving techniques used by other areas of engineering; chemical engineering and mineral engineering for extractive metallurgists, and mechanical engineering for the physical metallurgist. In many cases these courses already exist but are not taken by metallurgists. To us, this is an additional reason for supporting further strengthening of the effort in extractive metallurgy.

We can now speak specifically to the general recommendations given in the report based on the general classification of metallurgy and materials.

Recommendation #1 calling for further strengthening of the effort in extractive (chemical) metallurgy is one we support fully. For the reasons given above, we also support Recommendation #2 for maintenance in Ontario of top-level strength in materials science. Recommendation #3(a) recommends combining and augmenting of metallurgical, ceramic and polymer engineering into a strong program of materials engineering. This we can support as a suitable direction to move, but we hold to our claim above that these older classifications have much still to offer in the Canadian context. Recommendation #3(b) calls for an increase in the work on ceramics and glasses within materials engineering, and here again we affirm our support. It is clear also then that we support, as an important development to be fostered, a strong polymeric materials program integrated with a general materials engineering program (recommendation #3(c)).

We support fully the tenor and the conclusions of the report's detailed discussion on the supply and demand for highly-qualified manpower. There is a convincing criticism of the approach taken in the "Ring of Iron" and, more importantly, because of its recent nature, of the shortcomings of the CEMC report. We consider that the case made for increasing demand in materials science and materials engineering is a valid one, as is that for the area of extractive metallurgy when it is coupled with the cautious predictor of a somewhat slower increase. Contrary to an opinion in the report, we expect to see a drop in the number of metallurgists hired from the U.K., where we understand there has been a recent sharp drop in enrolment in both Ph.D. and undergraduate metallurgy programs. This only reinforces the concern that Ontario must produce more of its own, through both the attracting of more students into the undergraduate area and through the broadening of the base from which Canadian first-degree Ph.D. candidates are drawn. In addition, the short-term financial benefit of enrolment in a Ph.D. program is not great, and we hold the opinion that many Canadian graduates are thus easily attracted immediately into industrial employment. The "importing" of foreign graduate students is certainly in part a compensation for this. The latter, in our experience, usually have excellent academic qualifications, and many adapt adequately to the Canadian scene with a successful employment record. Nonetheless, if Ontario wishes Canadian graduates to direct the complex technologies of the future, it may well have to pay enough to attract them into a Ph.D. program. This may mean that students in particular areas will be paid more than others, but this precedent has already been set in the medical sciences.

We therefore strongly support both recommendations of the report with respect to an increase in the output of Ph.D.'s, and an intensification of recruiting efforts from Canadian undergraduate programs including an increase in stipend payments.

In addressing the recommendations specifically dealing with McMaster, we are pleased to note that the efforts we have put into our materials science program have resulted in facilities and programs that have been so enthusiastically praised. We are already trying to put more effort and imagination into recruiting chemists and physicists into our materials program. We recognize our lack of experience in the field of physical properties of polymers, and are looking for a postdoctoral fellow to help fill this gap. A faculty position in this field is a departmental priority. We also recognize that we have a relatively small number of faculty in extractive metallurgy, and we are presently planning to augment this field of activity through the addition of associate members from industry. We are also examining the breadth of our courses in this area. We anticipate more involvement with our other engineering departments, particularly chemical and mechanical engineering, and with the Department of Metallurgy at the University of Toronto. Overall, the suggestions and recommendations respecting our programs are both perceptive and pertinent. Irrespective of the future of the adoption of the report, we are appreciative of these recommendations and are endeavouring immediately to implement them as far as possible.

Our commendation of the report and our support for its recommendations arise in part from our appreciation of the analysis by the consultants of the data supplied to them. The statistical compilations of populations, undergraduate activities, graduate student data, sources of support, employment, etc. were executed to lend strong visibility to the time dimension (four to five year history) and to important factors for quality assessment. We wish to add only two minor points of comment. Firstly, more observations might well have been drawn from the interesting data on the total elapsed time for Ph.D. work. Its compilation for the system is nonetheless a most useful contribution. Secondly, we feel that the apparent confusion on the number of graduate students in particular programs arose from different interpretations of the term "materials engineering". The graduate students listed in materials engineering in our submission are taking a Ph.D. in metallurgy. Our delineation was not clear-cut, but was meant to indicate which students are more oriented toward metallurgical processing.

22 November, 1973

C-14

QUEEN'S UNIVERSITY
KINGSTON, ONTARIO
SCHOOL OF GRADUATE STUDIES AND RESEARCH

November 13, 1973

Dr. M. A. Preston
Executive Vice-Chairman
Advisory Committee on Academic Planning
Ontario Council on Graduate Studies
102 Bloor Street West
Toronto 181, Ontario

Dear ~~Dr. Preston:~~ Fred

The University wishes to render no comment, at this stage, on the final consultants' report on the Metallurgical Engineering Planning Assessment.

Yours sincerely,

Bob

R. McIntosh
Dean

RM/mjc

cc--Dean Robert J. Uffen, Applied Science
    Dr. W.B.F. MacKay, Metallurgy

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto 181, Canada

November 20, 1973.

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Council of Ontario Universities,
102 Bloor Street, West, 3rd Floor,
Toronto, Ontario.

Dear Dr. Preston,

The University of Toronto agrees with the broad thrust of the report submitted to ACAP by the consultants in Metallurgical Engineering, but finds inconsistencies of logic in some of its recommendations.

We should like first to respond to the general recommendations on page A-1 and then to consider recommendations and comments concerning the Department of Metallurgy and Materials Science at this University.

General Recommendations

1. It seems to us inconsistent to recommend expansion of extractive metallurgy in the system when the consultants state that the shortage exists in materials science and in materials engineering, for each of which expansion is recommended in only one university. The consultants have not made their case in terms of the numbers of graduates needed in extractive metallurgy; the need is in the other areas noted. Expansion of extractive metallurgy throughout the system might in fact weaken existing programs.

2. and 3 a, b, c. We agree, therefore, on the need for expansion in materials science and materials engineering with the qualifications which we shall add below.

Enrolment

1. Once again the Canadian Engineering Manpower Council Report estimates are shown to be highly dubious and it appears that there may well be a shortage of Ph.D.'s in metallurgical engineering.

2. We agree with the intent of this recommendation, we would suggest that, besides providing increased stipends to attract Canadian undergraduates into Ph.D. studies, the discipline give some thought to improving its "visibility" among undergraduates in Canadian faculties of engineering and faculties or departments of science.

The University of Toronto

We can see no reason to change the name of the Department of Metallurgy and Materials Science. The undergraduate and masters' programs adequately justify the present name. Inevitably both materials science and materials engineering must exist and there is need for strength in both areas.

The University of Toronto would hope to maintain and, where feasible, strengthen its materials science program. As the consultants themselves say of materials science (p. A-8) "The subject is an essential component of the education of all engineers who are to be associated with materials." The internationally recognized physical metallurgy group constitutes an important part of the materials science strength of the department as well as contributing to the interdepartmental work in materials engineering associated with the Materials Research Centre. The department's entry in the calendar of the School of Graduate Studies will be revised to include a separate program for materials science. This entry will be framed by the chairman and will indicate where necessary relevant course offerings of other departments. The consultants recommend staff additions in materials engineering (p.A-29), but in the opinion of the department any additions should be in materials science, particularly in physical ceramics and/or glass science and in polymeric materials. The faculty dean has asked that consideration be given to appointments in one or more of these areas, but the university can give no commitment to such appointments at present.

Groups now exist within the Faculty which could contribute to a materials engineering program, and the materials engineers within the Department of Metallurgy and Materials Science would form part of this interdepartmental group. The basis of co-operation could be widened to include members of the faculties of Dentistry and Medicine. The Materials Research Centre would form the organizational umbrella for such a program.

Given its excellent standing in extractive metallurgy, the University of Toronto recognizes its capacity to develop the field of mineral engineering. The Department of Metallurgy has just introduced an undergraduate program in mineral engineering with the intention of eventually building a viable graduate program in this area. After the closing of the faculty's Mining Department in 1967, two staff appointments were transferred to other departments and a third lost through retirement. The first two appointments will retire within the next two years and the faculty will give sympathetic consideration to maintaining these positions for appointees in mineral engineering.

The University of Toronto is aware of the space problems of the Department of Metallurgy and Materials Science and the Materials Research Centre. The housing situation of both will be reviewed as part of a general reconsideration of the program needs discussed above.

We accept the principle of co-operation expressed on page A-3 which we believe merits separate provincial funding. The University of Toronto would be willing to participate in a pilot study with McMaster University in the use of a TV talk-back network.

Yours sincerely,

A.E. Safarian

:erb

A. E. Safarian,
Dean.

Response of the University of Waterloo
to the Report of the Metallurgical Engineering Consultants
to the Advisory Committee on Academic Planning

submitted to ACAP, November 15th, 1973

We find this report to be generally of high quality and we wish to commend the consultants for the excellent job which they have done. We will begin this submission with a few general comments on the report. We will make specific comments on the section devoted to the University of Waterloo and finally will summarize our position on the recommendations.

General Comments:

The report begins with a very good description of the nature and historical development of the field being assessed. Work in metallurgical engineering, materials engineering and materials science has never been as clearly identified as a discipline within the university context as work in the other major engineering fields and in particular has never had a large clearly identified undergraduate base to draw upon for graduate students. Graduate students in the materials field generally come to it with a diversity of backgrounds from other engineering departments or from departments of physics and chemistry. In our view, this situation is likely to continue as long as work in this field remains as diversified as it is currently. We agree with the consultants that graduate work in the materials field should be strengthened and we support their first two recommendations which are stated at the conclusion of this section of the report. We also support the goal which the consultants wish to achieve by Recommendation 3 but we question the mechanism. It is not obvious to us that combining these diverse activities under a single administrative structure will necessarily lead to the kind of coordination and strengthening of the programmes that the consultants desire. Such an arrangement might be successful in some cases but not in others.

We support fully the consultants' analysis of the supply and demand for manpower in this field. In particular, we support the recommendations contained in this section of the report. The particular problem of low Canadian content in the graduate programmes which the consultants comment on is present in other engineering programmes. We can only repeat here what we have said in response to the other reports, namely, that we will continue to make every effort to attract Canadians into graduate work in this field. At the same time, we will ensure that foreign students in the programme are of high quality. We agree with the consultants that increasing the stipends paid to graduate students would make it more attractive for Canadians to undertake graduate work.

Specific Comments:

In the section of the report devoted to the University of Waterloo which begins on Page A-33 the consultants make the statement that "There is no graduate programme in materials at the University of Waterloo and consequently, there is no Ph.D. degree in metallurgical engineering or any allied field.". In the sense which the consultants use the term "graduate programme in materials" this is a correct statement. The substantial research and graduate activity at Waterloo in materials which the consultants discuss at some length is part of the graduate programme in Mechanical Engineering. It is not designed to produce materials engineers or metallurgical engineers but rather to provide a strong programme in materials for mechanical engineers. The inclusion of this activity within the Mechanical Engineering Department has been a matter of conscious planning by the Faculty of Engineering. As a result, this activity is well integrated with the work of other groups in the Mechanical Engineering Department; one function of the materials group is to provide strong support for work in mechanics, design and production engineering. It has also played an important role in the development of the undergraduate programme in mechanical engineering. The success of this effort has been pointed out by the Mechanical Engineering consultants in their report to ACAP in which they say "We are intrigued by this effective combination of resources, commend them on this approach, and recommend its continuance.". It is probably true that the visibility of the group has suffered by this arrangement and steps are being taken to rectify this. On the other hand, it has provided the graduate programme in materials with a large undergraduate base.

The University of Waterloo must reject the suggestion that this group should be established as a separate department or given some other administrative identity within the Faculty. We believe that such a step would adversely affect the role which it is now playing within Mechanical Engineering and would be inconsistent with the philosophy of integrating a strong materials activity within the engineering departments.

The consultants also comment on the fact that there are courses in materials offered in the other departments in the Faculty of Engineering. This has occurred because of the recognition in the Faculty of the important role which materials play in all branches of engineering. The consultants suggest that the university should draw this activity together in an administrative unit to carry out a graduate programme in materials engineering. At the present time the university has no plans for such a development. We will continue to encourage cooperation amongst the various groups and will work to coordinate the programmes in the different departments. We will also continue to encourage the development of interdisciplinary activities across Faculty boundaries whenever these show promise of evolving. We are not convinced that the establishment of an administrative unit to encompass all of this activity would be a wise course of action for the university to take at this time.

Comments on Recommendations:

We conclude by summarizing our position on the several recommendations set forth by the consultants.

We support Recommendations 1 and 2 and Recommendation 3 with the caveat that we do not consider it necessary to provide an administrative linking of programmes in order to achieve a viable level of cooperation and coordination. The University of Waterloo intends to maintain the strength of its graduate work in materials and to continue to develop cooperative arrangements between the various groups working in this field.

We support the recommendation with regard to the anticipated demand for Ph.D.'s, namely, that it be at least double the figures given in Table 58 of the report of the Canadian Engineering Manpower Council.

We support the recommendation that efforts to recruit a larger proportion of Ph.D. students from Canada should be continued and intensified.

We support the recommendation that graduate programmes in materials science and materials engineering should be made attractive to students from other subject areas. Indeed the University of Waterloo's programme has been deliberately so designed. It attracts students from other engineering departments as well as students with backgrounds in physics and chemistry.

We cannot accept the recommendation that the Faculty of Engineering at the University of Waterloo re-examine the proposition that some administrative and organizational structure be developed to give coherence and visibility to a graduate programme in materials engineering. Our reasons for rejecting this recommendation have been set out in some detail above.

Finally, we support the recommendation that more attention be given to inter-university cooperation in the metallurgy materials field. We would add that this cooperation and collaboration should exist not only between universities but between universities and industry. The University of Waterloo's group in metallurgy and materials has developed very fruitful relationships with industry and will continue to do so.

Response of the University of Western Ontario to the Report of the Consultants on Doctoral Programs in Metallurgical and Materials Engineering of the Advisory Committee on Academic Planning.

November 9, 1973

This report was prepared by a Committee of Senate charged with generating a response to the ACAP Consultants' report on doctoral studies in Metallurgical and Materials Engineering.

(1) The committee compliments the authors on a careful analysis of the metallurgical and materials science area and on a clear statement of position with respect to the "Ring of Iron" and the "Canadian Engineering Manpower Council Report". We are inclined to accept the consultants' opinion in preference to those expressed in the reports noted above.

(2) The principle recommendation with respect to the University of Western Ontario on page A-37 is acceptable to this University in the following context. It is the intent of the Faculty of Engineering at the University of Western Ontario, as it has been since the program was initiated in 1967, to offer a doctoral degree in Engineering Science. The basic concept of this program is that a relatively broad spectrum of engineering subjects are open for study and that particular emphasis is placed upon interdisciplinary subjects which tend to bridge the traditional disciplines of Engineering but which have increasing relevance in modern society. In this respect we would note that the authors of the report defined two alternative positions in the discussion of critical size (see page A-22). Without commiting themselves to either alternative, they, in fact, opted for the American position when they came to discuss the University of Western Ontario since the principal reservation about the program is that it is of "sub-critical size" (page A-37). It would be our opinion that when viewed in the context of an Engineering Science program with course work and research support derived from other groups in the faculty outside the immediate subject of review that the program readily meets the criterion of critical size.

(3) In the report of Civil Engineering we commented upon the possibility (paragraph 3(c)) that engineers who have professional qualification who might undertake graduate study could be supported at levels higher than those generally prevalent in graduate schools. If it is the belief of funding agencies that commitment on the part of Canadian students to engineering graduate studies should be increased, it is open to them to foster this by making graduate study in engineering somewhat more attractive financially than at present.

(4) We would like to comment on a development in the University of Western Ontario Materials Science program which received scant attention by the reviewers but which we believe to be a useful adjunct in the training of research students. Five out of the ten students currently enrolled in materials science group have established contacts with industry in such a way that they spend part of their time in industry and part of their time in the University. This practice, which has become popular with the industries involved, serves two functions - it provides the student with much needed practical

experience in the "real" world of industry and also supplements the income which the student may earn while at University. This practice appears to us to be a valuable technique in the training of graduate students which might be more widely explored.

We hope these comments are of some help to you. There will follow a comprehensive statement dealing with the five discipline assessments when we have had an opportunity to adequately examine the individual reports.

A Response of the University of Western Ontario to the Advisory Committee on Academic Planning with respect to the Engineering Specialty Assessments (1973).

November 29, 1973

Historical Aspects

Approximately 20 years ago (1954) on the recommendation of the Faculty of Arts and Science the Senate of the University of Western Ontario established a Department of Engineering Science. This Department undertook to gather the faculty necessary to establish an independent Faculty of Engineering Science and Faculty status was granted to this group in 1960. The beginning of formal graduate study was the offering of an M.E.Sc. program which received the approval of the Faculty of Graduate Studies and Senate in 1961. The first candidates (4) were admitted in September 1962 and by 1964-65 the number of M.E.Sc. candidates had risen to 18. In October 1964 the Faculty of Graduate Studies approved the establishment of a Ph.D. program in Engineering Science and the Senate supported this action on January 29, 1965. From the outset an effort was made to emphasise the interdisciplinary nature of the program and graduate training was offered in a limited number of areas which at that time included chemical and biochemical engineering, soil mechanics, structural engineering and thermodynamics. Since its inception the Ph.D. program has produced a number of graduates

1969	-	1
1970	-	1
1971	-	6
1972	-	6
1973	-	6

In 1973-74 there were enrolled in the Ph.D. program 29 full-time students and 15 part-time students. All of these students have received or are enrolled in programs leading to a Ph.D. in Engineering Science and none of them has received a degree designated as serving one of the traditional specialties of engineering (e.g. chemical, mechanical, etc.).

The "Ring of Iron" published in 1970, among other things, recommended that the Faculty of Engineering Science drop the "Science" from its name (Ring of Iron, p. 77). The Faculty, after considering this matter, elected to retain this name as it did its interdisciplinary programs. The "Ring of Iron" did recognise the interdisciplinary nature of the programs by recommending that Western "concentrate" on environmental engineering which was acknowledged at that time to be a foretaste of the future. At that assessment it was also noted that "Western has gained distinction with its work in industrial aerodynamics, electrostatics and bioengineering". (Ring of Iron, p. 76).

Present Assessment

As a consequence of dissatisfaction with the stringency of Ph.D. recommendations in the "Ring of Iron" as adopted by the Council of Ontario Universities, the Council of Deans of Engineering has sought a reassessment of the Ph.D. programs in Ontario Engineering Schools. This task was undertaken under the aegis of the Advisory Committee on Academic Planning and something which has been erroneously termed a "mini-appraisal" has been performed.

The conditions under which this appraisal was undertaken are of particular interest because the form which this assessment has taken fails to take cognizance of work of an interdisciplinary nature which may be deemed to be outside the traditional specialties of civil, electrical, mechanical, chemical and metallurgical and materials sicence engineering. Examination of the five reports which have been received reveals rather remarkable differences between reports in spite of the fact that the consultants seem to have been given substantially equivalent instructions (with the possible exceptions of mechanical and chemical groups who do not specifically report their terms of reference). Remarkable perhaps are the prevalent comments about "critical size" when the printed terms of reference contain no mention of critical size.

As the present assessment has been conducted, it seeks to determine whether the engineering schools of the province contain five individually certifiable traditional specialties of engineering. If this was the objective of the assessment it was not so stated in advance. Not surprisingly, the large schools with substantial groups in each of the specialties survive assessments of this sort. The smaller schools regardless of the quality of their operations when judged in this particular frame of reference are found wanting in one or more of the traditional specialties. That is not to say that the discipline is not represented in the school since it must be to meet undergraduate instructional needs but the group practising the specialty is small and does not meet some arbitrarily defined critical size.

What can a school that is faced with this difficulty do? Aside from the obvious and in general unacceptable possibility of retiring from competition the researcher in the small "sub-critical" groups seeks to meet the need for interaction with other professionals and to develop his own intellectual pursuits by developing liasons with other individuals in related fields. The consequence is that individuals with different backgrounds, information and skills address themselves to problems which they have in common. At its best this kind of development can be the most exciting research conceivable. At its worst the products of the activity may be minimal or zero. However, we would contend that operations of this sort which stem from small interdisciplinary groups are potentially of great importance and furthermore, that the present assessments carried out along stereotyped lines may not detect these activities and are likely not suited to the evaluation of them.

It will be evident that interactions with individuals in other disciplinary specialties, however integral to the research in hand, will not permit the specialist group sparsely represented on staff to meet the criterion of critical size when the assessment is carried out in the framework of traditional disciplines.

The situations which prevail at Western in which these difficulties of assessment are most easily identifiable lie with the Electrical and Materials Science groups although the prevailing interdisciplinary attitude of faculty members in other groups leads to a reduction in the vertical integrity of the traditional specialties and to an enhancement of horizontal interactions between specialties. Encouragement of this horizontal interaction has been a conscious policy within the Faculty of Engineering Science and is a major determining factor in the decision of the Faculty to offer an Engineering Science program rather than programs in the traditional specialties.

The Engineering Science Concept

The absence of departmental structure and all that it contributes to specialty tribalism, the limited dimensions of the Faculty (approximately 43 F.T.E.), and the existence of congenial relations has led to development of extensive interaction and collaboration between groups within the Faculty. For similar reasons it has also been possible to develop interfaculty research activities in the biomedical area, (collaborative activities in both biomedical engineering and applied physiology), in radioscience (as participating members in the Centre for Radioscience) and in computer science (where the systems engineering group has developed a collaboration). The abiding interest of the Faculty in environmental matters has promoted interaction with other parts of the University which may be expected to bear fruit in the future. It should be noted that in all five of the assessment reports the comments on the quality of the work in hand were favorable.

In effect, circumstances have dictated that a particular course of development be followed. It would be our contention that this course has led to much that is valuable and worthy of development. While the route we pursue may be inappropriate to other Engineering Schools we would request that we be judged in this framework and not in the traditional format which cuts across rather than displays our most effective activities.

These remarks may be concluded by a statement that as recently as November 14, 1973 and with the full knowledge of the various consultants reports, the Faculty of Engineering Science reaffirmed its intent to continue to offer undergraduate, masters and doctoral training in Engineering Science and not in any of the specific sub-disciplines.

FORMAL STATEMENT
# of the
UNIVERSITY OF WINDSOR
to the
REPORT OF ACAP CONSULTANTS
FOR DOCTORAL STUDIES
IN METALLURGICAL AND MATERIALS ENGINEERING
IN THE PROVINCE OF ONTARIO

The response of the University of Windsor to the final report of the ACAP consultants for Metallurgical and Materials Engineering and the recommendations contained therein, is herein presented in the form of a general commentary on the philosophy and criteria used by the consultants in formulating their recommendations, followed by comments on the general recommendations and the specific recommendation for the Department of Engineering Materials at the University of Windsor.

REPORT'S APPARENT CRITERIA

In developing the arguments which lead to the general and specific recommendations, the report considers three factors, of which the consultants' assessments constitute the philosophy or criteria for the recommendations. These factors are:

(1) Interpretation of "Metallurgical Engineering"

Metallurgical Engineering has been subdivided into three principal parts: extractive (chemical) metallurgy, materials science, and materials engineering. There is little difficulty in differentiating extractive metallurgy from the other two branches which form the discipline more generally known as "materials". The former is concerned primarily with the extraction of metals from minerals and ores, and therefore, heavily dependent on chemistry and chemical engineering processes. The report argues that although extractive metallurgists are often found together in the same department with physical metallurgists (classed as materials scientists or engineers), their divergent interests have not been an effective cohesive force. We concur with the report that "it is feasible, and sometimes by force of circumstances necessary, to have sound physical metallurgy, materials engineering or materials science without any interaction with extractive metallurgy".

Materials science is differentiated from materials engineering on the general assumption that the central theme of materials science is the relationship between structure and properties, and is therefore concerned principally with solid-state physics and solid-state chemistry, while materials engineering deals with solving specific problems and utilizes the best available materials science. This differentiation appears to have some rational basis; however, it is impracticable and unsound to attempt any strict classification of materials research projects according to the science or engineering content. It is impossible in many research projects to determine where science leaves and engineering enters or vice versa. Thus, as a general rule, there is no justification to preclude a materials science or materials engineering department from undertaking a particular materials research project on the basis of the supposed content of science or engineering.

We concur with the report's differentiation between the general themes of materials science and materials engineering; however, we hold it to be impracticable, impossible and detrimental to attempt any strict classification of specific research problems or graduate courses according to their science or engineering content.

(2) The Supply and Demand for Manpower

The report has performed an invaluable service to the profession and country in its clear and well substantiated refutation of future PhD manpower supply and demand as projected in the Ring of Iron and the Canadian Engineering Manpower Council report. We concur with the report's recommendation that "the figures for anticipated demand in 1974-75 for PhD's in Ontario in "mining, metallurgy and materials" be at least double those given in Table 58 of the report of the Canadian Engineering Manpower Council, July 1973, and the targets for the total PhD student population in these disciplines be adjusted accordingly". However, we reject the remainder of the same recommendation, viz., that "most of the necessary substantial increase in the output of PhD's should be from departments with comprehensive programs in materials engineering or materials science or both", since it does not explicitly direct that there should be a proportionate increase in the supply from the smaller institutions.

We also concur with the report that "efforts to recruit a larger proportion of the PhD students from the graduates of Canadian undergraduate programs should be continued and intensified. The stipends paid to Canadian graduate students are inadequate to attract a sufficient number and should be increased substantially".

(3) The Quality of the Educational Experience

The report is clearly biased in favor of the American system as compared to the British system for graduate studies and research, i.e. considerable emphasis is placed on formal course work. In the British system, the graduate program is centered around the thesis, and formal courses play a relatively small role. In favoring the American system over the British there follows the inevitable corollary that only large departments can provide a good range of formal courses from which the student can select those courses which fit his particular needs. However, the report does not attempt to define the term "critical size" quantitatively when discussing the number of faculty members required for a viable program.

Although the report clearly favors the American system with the concomitant large departments, it nevertheless admits that "no obvious correlation exists between the performances and achievements of PhD graduates and the system in which they were educated". This admission cannot be passed over too lightly, for in its correct explanation lies the answer to the question of relative superiority of the two systems. At the very least it refutes the argument that the American system is superior and to be preferred as groundless. Having failed to provide any documented evidence in support of the superiority of the American system, the report then makes the dogmatic assertion that "a graduate program should be judged by the quality and range of opportunities it offers to the student, not by the achievements of occasional outstanding individuals who may have gone through the process in the past", and so very deftly circumvents the onus of explaining how some "occasional outstanding individuals" obtained their graduate training at smaller institutions.

The emphasis of the report on the virtues of bigness should not come as a surprise since two members on the committee of consultants, of which one is the chairman, are faculty members of one of the largest postgraduate institutions in the United States, whose metallurgy faculty alone almost equals the total engineering faculty at the University of Windsor. The unique accomplishments of the smaller graduate schools in Canada are a matter of public record, and there is no intention or necessity to present a defence on their behalf in this report.

We reject the general bias of the report towards the American system and the concomitant preference for PhD programs at larger institutions, insofar as this bias and preference fails to recognize the unique advantages and accomplishments of the PhD programs at the smaller institutions. We concur with the report's admission "that most professors with a strong interest in research are unlikely to be content to work in a predominantly undergraduate environment", and hold that graduate programs are essential for the well-being of the undergraduate programs in engineering.

GENERAL RECOMMENDATIONS

We concur with the general recommendations of the report on page A-1 relating to increasing the graduate effort and the corresponding output of PhD's in certain areas of metallurgy and materials science and engineering. However, we reject the recommendation that "most of the necessary substantial increase in the output of PhD's should be from departments with comprehensive programs in materials engineering or materials science or both", since it does not explicitly direct that there should be a proportionate increase in the supply from the smaller institutions.

RECOMMENDATION FOR WINDSOR

In assessing the graduate program in the Department of Engineering Materials at the University of Windsor, the report correctly notes the recent reorganization of the graduate courses in the Faculty of Engineering into three divisions: Engineering Process Design, Structures, and Systems. It views the reorganization as beneficial, particularly in that it provides the students with a broader spectrum of graduate engineering courses and research, and also encourages interdisciplinary interaction in the faculty. The Engineering Faculty undertook the reorganization to rationalize the many and varied graduate courses offered in the Faculty of Engineering. The departments now offer their respective graduate courses under the administrative control of a particular division, to which the departments have imput through their faculty members. The principal function of the divisional structure is to minimize duplication by coordinating and combining similar courses offered by two or more departments, which then become the core courses for the division. A student is required to take a minimum number of core courses plus a number of more specialized courses required for his particular needs. The student is still under the jurisdiction of a particular department, and the degree is granted through the department. Thus the departments have not lost their identities as might be inferred from the statement in the report that "the PhD program in engineering materials has been absorbed by the new divisional structure".

The report acknowledges the good research productivity of the faculty members in the department based on the current rate of output of papers in refereed journals, and predicts they will make an excellent contribution to the research program in the new divisional structure. The report then specifically recommends and encourages present efforts to integrate the graduate program within the divisional structure. We interpret the above comments and recommendations to be an acknowledgement of the high quality and productivity of the PhD program in the department, and an explicit directive for its continuation within the faculty-integrated divisional structure.

The Department of Engineering Materials of the University of Windsor currently offers, and shall continue to offer, its PhD program in engineering materials through the faculty-integrated divisional structure. The integration of the graduate program into the divisional structure provides the graduate student in engineering materials a comprehensive range of applied science and engineering courses. The Department is well equipped in laboratory facilities and supporting technical personnel for research in the physical-mechanical and processing fields of materials at the PhD level, which it has very successfully done in the past as evidenced by the Department's publication record and past output of PhD's.

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APPENDIX D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Procedure for Metallurgical Engineering Doctoral Planning Assessment
conducted by ACAP in co-operation with CODE

1972-73

A. Tasks Requested from Discipline Group (with help available from ACAP at all stages)

A.1. Meet with representatives of ACAP and CODE and discuss the specialty fields assigned to this assessment. An initial meeting of the five engineering discipline groups may prove desirable. The field allocations may be altered by ACAP as a result of these discussions and CODE comment.

A.2. Suggest a panel of suitable consultants from which ACAP may choose. ACAP will refer the list to CODE for comment before acting.

A.3. Examine and comment on pro formae to be used for the gathering of information on current, past and future programmes as described in paragraph B.1.

A.4. Examine and comment to ACAP on the adequacy of the data collected on current and past strength. CODE will also be asked to comment on the data reliability.

A.5. Both in consultation with ACAP/CODE representatives and separately, consider the situation revealed by the tabulation of proposed future programmes and consider whether future plans should be modified or developed in more detail. As a result of this step, individual universities may wish to revise the material described in B.1.d below.

A.6. Possibly develop a tentative plan for development of established or new doctoral work in Ontario paying attention to adequate coverage of fields and specialties. Any such plans will be reported to ACAP which will transmit them to the consultants and to CODE.

A.7. For this assessment, the discipline group shall consist of a member of each of the Departments of Metallurgical Engineering, that member being the chairman unless the chairman delegates this responsibility to a colleague on a permanent basis.

B. Information from Universities

B.1. Each university is asked to supply to ACAP, in the form indicated by ACAP after comment by CODE and by the discipline group (paragraph A.3.).

information as follows:

a) for each specialty field determined in A.1.

- (i) current list of faculty members showing fraction of research and graduate instruction time devoted to the field (for part-time professors show the time spent on university duties);
- (ii) numbers of full-time and part-time faculty members for each of the past five years;
- (iii) for the current year and preceding five years, number of (1) master's and (2) Ph.D. candidates and (3) post-doctoral fellows doing research in the field full and part-time shown separately.

Under these three headings one individual may appear under more than one category.

b) for each "department" which offers doctoral work in the fields of this assessment

- (i) Curricula Vitarum of each faculty member (Assistant Professors and higher) showing inter alia complete publication lists, research funding in the past five years, and graduate students and post-doctoral fellows supervised during his career, and specialization.
- (ii) resources of space - a statement indicating the department's view of the adequacy of its space, and, in connection with the future plans in (d) below, discussing future space provision;
- (iii) number of Bachelors' graduates in metallurgical engineering and number of qualifying or make-up students each year for the last five years;
- (iv) other general items relevant to research and graduate study,
  - a) major laboratories and equipment, over $5,000
  - b) computing facilities;
- (v) support from related departments including shared teaching and research;
- (vi) description of any inter-university arrangements for graduate work.

c) table of characteristics of graduate students in the department in previous five years, separately for Master's and Ph.D., breaking down numbers by:

- (i) Full-time and Part-time;
- (ii) immigration status (3 years) and country of first degree;
- (iii) sources of financial support;
- (iv) time to reach degree;

(v) drop-out number;

(vi) degrees granted;

(vii) post graduate employment of Ph.D.'s
  a) immediate and
  b) after two years.

d) proposed plans for the future of doctoral work, in as much detail as the department can provide, including the proposed scheme for support of these plans, and accompanied by supporting arguments, including consideration of the sources of doctoral students and an analysis of demand for graudates from the programmes as indicated by previous placement experience. The various headings in a) and b) above should be dealt with quantitatively where possible; as a minimum, planned numbers of faculty and doctoral students should be given. If part-time doctoral work is contemplated, please discuss in detail.

B.2. The material so supplied will be collated by ACAP and transmitted to the discipline group for action indicated in paragraphs A.4., A.5 and A.6.

B.3. Apart from the material described in B.1.d. and to some extent generated at the department level, each interested university will be requested to make an individual statement on its plans for the development of doctoral work in these fields of engineering, in particular the items of future commitment implied by item B.1.d.

C. Terms of Reference of Consultants

C.1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering Ph.D. Planning and Assessment Procedures, Statement on Ph.D. Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

C.2. Report on the adequacy of the present state of doctoral work in "metallurgical engineering" in the province in general and in each university where applicable, discussing the following:

a. coverage of fields and specialties, and extent of activity in each

b. faculty quality and quantity

c. nature of programmes offered

d. enrolment size and distribution amongst universities and divisions

e. quality of student body; admission requirements

f. relationship to related disciplines and to the profession

g. physical facilities

h. other matters considered by the consultants to be significant.

C.3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study **in metallurgical engineering and in the major subject divisions where** appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

C.4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section C3 (c).

D. Appointment of Consultants

The consultants shall include one person of wide academic experience in Canada but in a different discipline. The other two consultants shall be engineers of international standing, with suitable administrative and/or teaching experience, and with expertise in some of the fields assigned to the metallurgical engineering assessment.

E. Report of Consultants

The consultants submit a joint report to ACAP (tentative date of September 1973). Minority reports are, of course, possible. The reasoning leading to their recommendations should be given fully, in view of the subsequent treatment of the report. The report is submitted for comment to CODE, to the discipline group and to each interested university. There may be informal or interim exchanges of views amongst the discipline group, the universities, CODE and ACAP. Any university which wishes to make a formal statement to COU on the consultants' report shall submit it to ACAP. Any such report shall be transmitted to CODE and to the discipline group. The discipline group shall submit its formal comments and/or recommendations to ACAP and CODE. CODE submits to ACAP its recommendations to COU. ACAP considers the CODE, discipline group and university statements along with the consultants' report and transmits them to COU with its recommendations of the position COU should adopt. Copies of the material transmitted to COU will be supplied to CODE, to OCGS, to the members of the discipline group and to the interested universities. CODE, OCGS and the universities are thus enabled to prepare for direct comment to a COU meeting. The consultants' report may be published together with the comments of CODE, the discipline group and those of any university so requesting, and with the position adopted by COU.

Amended November 29, 1972.

Engineering Ph.D. Planning and Assessment Procedures

Coordinating Task Force, September 25, 1972

1. The doctoral assessments in Engineering are being conducted as a group. To that end there has been established a Coordinating Task Force to coordinate the conduct of the assessments in accordance with the procedures outlined in this document which is referred to in section C1 of the Terms of Reference for the Consultants.

2. All "departments" of each Engineering Faculty shall prepare a statement presenting their current and proposed Ph.D. activities including:

   (a) areas of research and study
   (b) educational goals and style
   (c) enrolment ranges projected to five years, and other items as defined in section B of the approved "Procedure", including the basic ACAP quantitative data sheets as modified for the engineering assessments.

   The quantitative data sheets, to be submitted to ACAP by November 1, 1972, and the "five-year plans", due by the end of January 1973, will then be distributed by ACAP to the discipline groups for consideration and planning action by the individual institutions and by the discipline groups. Copies will be made available to the members of CODE.

   Departments are encouraged to discuss their preliminary plans with the appropriate discipline group prior to formal submission in January and the discipline groups should be active in their planning function throughout this period.

3. Each Discipline Group will be charged to prepare from the statements a report on Ph.D. activities and plans in their discipline area, noting both apparent conflicts and gaps in both areas of specialization and enrolments. Reports will be distributed as above, by the end of February 1973.

4. Each University may modify the above statements in the light of the above and in consultation with the Discipline Groups ~~and other~~ Universities as appropriate. Subsequently the Discipline Groups will finalize their reports, which are due to ACAP by April 15, 1973.

5. These statements and reports, along with the regular ACAP assessment data (to be prepared during the above process, perhaps with CODE "data bank" collaboration) shall form the data base for the assessment teams. Failure to meet deadlines will not be allowed to delay proceedings.

5. The Coordinating Task Force will review the detailed terms of reference to be given to the consultant teams, particularly in the educational professional areas. This is scheduled for completion by September 30, 1972.

6. Upon completion of (4) above, the Coordinating Task Force shall recommend to CODE and ACAP whether areas in Engineering not clearly included within the five major discipline areas shall be included within the total of engineering activity without further review, or included within one or more of the major discipline studies, or be subject to a small special assessment process.

7. CODE, with assistance from COU and utilizing outside expertise as needed, shall implement a special study of the engineering manpower situation at the Ph.D. level. This study should be available for consideration by ACAP, the Discipline Groups and the consultants prior to the drafting of final reports and responses. Reports on the progress of this study shall be reviewed by the Coordinating Task Force; the first report shall be due by the end of 1972.

8. The formal assessment and consultative process shall commence on completion of (4) and the consultants shall be provided with a general statement, in addition to the data base material, terms of reference, and other relevant documents. This statement which has been prepared by the Coordinating Task Force and is referred to in section C1 of the Terms of Reference for the consultants is intended to draw attention to some features of the Ph.D. in Engineering which the Task Force considers distinctive enough to merit particular consideration by the consultants. Educational, professional and research concerns will be emphasized. Briefings and discussions with ACAP and the appropriate Discipline Group will complete the first stage of this process. These discussions are expected to occur about one month prior to the first visits and the visits themselves will be concentrated in the month of May and June.

9. The next stage consists of consideration of the available material by the consultants, University visits, meetings with the Discipline Group, and the preparation of a draft report by September 1, 1973.

10. The draft reports will be made available to the Engineering Deans and to the Discipline Groups to provide for initial feedback to the consultants. There will be oral response from the Discipline Groups to the consultants. Following this the consultants will draft their final reports which will be followed by official responses from the above groups and finally by consideration by COU. (The above is intended to make clear that while feedback to the consultants from the Discipline Groups is desired and expected, the draft reports are not to be distributed for open discussions within departments.)

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APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

McMASTER - G.R. Piercy

QUEEN'S - W.B. Mackay

TORONTO - C.B. Alcock

WATERLOO - P. Niessen

WESTERN - J.D. Brown

*WINDSOR - W.V. Youdelis

*Chairman

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APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,
   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;
   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;
   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;
   (d) "university" means a provincially assisted university in Ontario;
   (e) "discipline" means any branch or combination of branches of learning so designated;
   (f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;
   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;
   (h) "programme" signifies all aspects of a particular graduate undertaking;
   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

   (b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities.

   (c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

   (a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

   (b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

   (c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

   (d) To supervise the conduct of each planning assessment approved by CPUO;

   (e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

   (f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

(a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

(b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

(c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

(d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

(e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

(f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

(g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

(h) generally to report and to make recommendations to the Council;

(i) to seek and receive advice from appropriate experts;

(j) to employ consultants in connection with planning assessments;

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the Universities of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

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APPENDIX G

CURRICULA VITARUM OF THE CONSULTANTS

JOHN J. JONAS

Born Montreal, Quebec, December 8, 1932

B.Eng., McGill, 1954
Ph.D., Cambridge, 1960

Steel Company of Wales, 1954-55

McGill University, Assistant Professor, 1960-65
 Associate Professor, 1965-73
 Associate Dean, Faculty of Graduate Studies, 1971-
 Professor, 1973-

Member, American Society for Metals
Member, American Institute of Metallurgical Engineers
Member, Institute of Metals (U.K.)

Visiting Lecturer, University of Sheffield, 1968
Visiting Professor, Chalk River Nuclear Laboratories, 1971
National Research Council Exchange Scientist, U.S.S.R., 1973 (Summer)

Mechanical metallurgy; elevated temperature deformation of metals and crystalline materials; dynamic recovery during hot compression and extrusion; substructure formation and stress-strain rate-temperature relationships during hot working

Address: Department of Metallurgical Engineering
McGill University
P.O. Box 6070
Montreal 101,
Quebec.

THOMAS B. KING

Born Scotland, April 27, 1923

B.Sc., Glasgow, 1945
Ph.D., Glasgow, 1950

Clyde Alloy Steel Company, Research Metallurgist, 1945-47
University of Strathclyde, Lecturer, 1949-53
Massachusetts Institute of Technology, Assistant Professor, 1953-57
  Associate Professor, 1957-61
  Professor, 1961-
  Head of Department, 1962-1972

Member, American Society for Metals
Fellow, American Academy of Arts and Sciences
Member, American Institute of Mining, Metallurgical and Petroleum Engineers (Director, 1964)

Metallurgical thermodynamics and kinetics

Address: Department of Metallurgy and Materials Science
Room 8-106
Massachusetts Institute of Technology,
Cambridge, Massachusetts
02139.

W. BENNETT LEWIS

Born Cumberland, England, June 24, 1908

B.A., Cambridge, 1930
M.A., Cambridge, 1934
Ph.D., Cambridge, 1934

Honorary Degrees:
DSc.: Queen's, 1960, University of Saskatchewan, 1964, McMaster, 1965
Dartmouth, 1967, McGill, 1969

L.L.D.: Dalhousie, 1960, Carleton, 1962, Trent, 1968, University of Toronto, 1972

University of Cambridge, Demonstrator, 1935-37
Lecturer, 1937-39
British Ministry of Aircraft Production, Telecommunications Research Establishment, 1939-46, Chief Superintendant, 1945-46

National Research Council of Canada, Director, Atomic Energy Division, 1946-52;
Atomic Energy of Canada Ltd., Vice-President, Research and Development, 1946-63
Senior Vice-President, Science, 1963-73
Retired, 1973

Order of the British Empire, 1946
American Medal of Freedom with Silver Palms, 1946
Public Service of Canada, Outstanding Achievement Award, 1966
Companion of Order of Canada, 1967
Atoms for Peace Award, 1967
Special Gold Medal, Canadian Association of Physicist, 1970
Fellow of the Royal Society
Fellow of the Royal Society of Canada
Member, American Physical Society
Fellow, American Nuclear Society, Vice-President, 1960
President, 1961-62

Radio activity; radio; electronics; radar; radiations; nuclear reactor physics; fluctuations; reactor economics and materials; fission gas behaviour; economics of nuclear power; high power accelerators

Address: Box 189
Deep River
Ontario

WALTER S. OWEN

Born Liverpool, England, March 13, 1920

B. Eng., Liverpool, 1940
M. Eng., Liverpool, 1942
Ph.D., Liverpool, 1950

University of Liverpool, Assistant Lecturer, 1946-48
    Lecturer, 1948-1954
    Henry Bell Wortley Professor, 1957-66
    Dean of the Faculty of Engineering, 1962-65
Massachusetts Institute of Technology, Research Staff, 1954-57
Cornell University, Thomas R. Briggs Professor, 1966-70
Northwestern University, Dean, Technological Institute, 1970-71;
    Vice President, Science and Research, 1971-73
Massachusetts Institute of Technology, Professor and Head of Department of Metallurgy and Materials Science, 1973-

Trustee, American Society for Metals
Member, American Institute Mining, Metallurgical and Petroleum Engineers
Member, British Institute of Metallurgy
Member, Iron and Steel Institute of Japan
Member, American Society for Engineering Education

Physical metallurgy of steel; deformation and fracture of solids; martensitic transformations.

Address: Department of Metallurgy and Materials Science
Room 8-309
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

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APPENDIX H

RESPONSE OF THE COMMITTEE OF ONTARIO DEANS OF ENGINEERING

COMMITTEE OF ONTARIO DEANS OF ENGINEERING

RESPONSE TO ENGINEERING PhD ASSESSMENTS

Preamble

Individual reports of PhD Assessments have already been received by discipline groups and by individual universities. Both bodies will undoubtedly make detailed commentary on the specific reports which are of direct concern or interest. In view of this, CODE has decided to forego comment on such specifics, and has determined to refer only to those matters of a more general nature which affect the universities collectively. In choosing to frame its response in unitary fashion, CODE wishes, at the outset, to emphasize that it views engineering education and practice as a total activity instead of a discrete set of unrelated disciplines such as Chemical, Civil, Electrical, Materials, Mechanical and Metallurgy, etc. This theme of relationships between disciplines within a faculty, and indeed between faculties, will recur later in the report in subsequent discussions.

Of the ten topics on which CODE sets out its 'responses', three are considered to be of primary importance - manpower, quality, and critical size. Consequently, they have been covered in somewhat greater detail than have other topics of interest, in order to provide identification and emphasis, rather than a fully developed 'position'.

The primary concern in this response is unquestionably that of quality over quantity. In assuming this position CODE realizes that the indicators of quality are undoubtedly staff, students, programmes and facilities. It is difficult to assess the precise hierarchy of these four basic parameters. Suffice it to say that, while the first two are paramount in terms of establishing potential for excellence, the last two are important in realizing this excellence.

CODE offers its resources in such further and subsequent amplification as may be useful to the purposes of the Council of Ontario Universities.

Manpower

CODE is in agreement with the general observations of the consultants with respect to the PhD manpower situation. It appears clear that the supply of PhD candidates will be limited by the availability of high quality entrants. The relatively small numbers of Canadian graduates entering PhD programmes is a cause for concern. If Canada is to advance industrially, it would be expected that there would be an increasing demand for high-technology support. An under-supply of PhD graduates in engineering would not be in the best interest of society. There is clearly no evidence of any over-supply because of the way engineering graduates at all levels are seen to diffuse widely through industry, commerce and government; there appears no prospect of this becoming a problem in the future.

CODE realizes the importance of maintaining up-to-date knowledge of positions taken by the PhD graduates of the Ontario Engineering schools and intends to ensure that such information is updated annually. A copy of a recent survey is included as part of this response. It will be noted from this survey that there has been a shift in the area of employment of engineering PhD's towards industry.

In the light of the consultants' analyses, and of the appended data, there is no need for quotas or ceilings on doctoral students. CODE will continue to report on the number and origins of doctoral students in the various engineering schools, on an annual basis.

Quality Emphasis

(a) Admission

CODE is pleased to note that the consultants have agreed that high admission standards to engineering doctoral programmes generally prevail.

CODE, therefore, supports the contention that existing minimum entrance standards to PhD programmes should be maintained across the Province. CODE believes that a *post facto* analysis of admission practices, widely publicized, will be adequate to ensure this objective.

In application of these standards, it must also be acknowledged that certain defensible exceptions will occur with respect to those with known special abilities or those who have demonstrated superior ability in research, design and innovation in their post-baccalaureate experience.

CODE fully supports the view of the electrical consultants that it is "in Canada's interest, especially in international competition, to have strength in high-technology research and development" and for this to happen there must be an objective of "high standards of excellence with emphasis on quality".

(b) Programmes and Faculty Facilities

CODE recommends that totally independent and representative bodies continue to oversee negotiated development grants and the formation of centres of excellence. These are matters better left outside the jurisdiction of such a body as CODE.

(c) Undergraduate/Graduate Programme Relationship

CODE supports the contention that the continued existence of a live, up-to-date undergraduate programme requires the backing of a good research programme and participation in professional practice by members of the faculty. The research activity, in the prevailing tradition, is most easily met through the provision of Master's and PhD postgraduate programmes.

(d) Quality Indicators

In addition to the observance of university regulations, and the use of high calibre external examiners, the observed career performance of doctoral graduates can be used as a 'quality indicator'.

Critical Size for Doctoral Programmes

In order to be viable, a PhD programme must provide a sufficient range of interaction for the student. He must be exposed to enough faculty members and enough other students to provide adequate breadth of experience and instruction. The adequacy of this breadth cannot be judged exclusively by the size of the department in which he is registered.

The ACAP assessments, by being completely vertical, miss the rich horizontal components which can and do nourish and sustain viable doctoral programmes in both small and large departments and faculties. Resources from other divisions of the university, other engineering departments, industry and, indeed, other engineering faculties must be considered in any realistic analysis of PhD programme viability.

Size is not a sufficient criterion for judging whether a school can offer a PhD programme; there is no *a priori* reason why a small school cannot provide as satisfactory an environment for the student as can a large school.

Engineering in the Wider Context

CODE would draw attention to the need to view the totality of the PhD programmes in engineering not just in isolation, but also in the context of other related disciplines; e.g. physical, life and social sciences.

To progress technologically in such a way as to improve the quality of life not only in Canada but also in other parts of the world, it is essential that there be work proceeding concurrently in the forefront of various other disciplines which impact on engineering. It is anticipated that increasingly advanced work in various areas will need to proceed in a more integrated fashion and it will be essential to have available high level manpower in the physical, life and social sciences, economics, and management, for instance, together with similar capabilities in engineering.

Research Emphasis and Relevance

As a result of the ACAP Engineering Assessments, there is now readily available information about research projects underway in all the Ontario

Engineering Schools. The system would have profited more had the consultants commented in detail on this information and offered substantiated specific advice on the topics of emphasis and relevance.

CODE feels that PhD programmes in engineering should be flexible enough to cover a broad range of topics. Research activities could and should range from mission-oriented research of an immediate and perceived social or industrial relevance through to very fundamental or basic research. The overall thrust of PhD research programmes should be towards advancing fundamental engineering knowledge required for the solution of present and future engineering problems.

CODE also ~~feels~~ that a plurality of sources of research support is a relatively effective means of ensuring that a broad spectrum of research activity is undertaken within the engineering schools. The existence of a variety of granting bodies, with a spectrum of interests represented, including a significant academic component, appears to be an effective method of control.

Level of Support for Doctoral Students

CODE strongly supports the contention that levels of support for doctoral students must be increased substantially if more Canadian students are to be attracted to entering doctoral programmes in engineering.

It should be noted that foreign graduate students have been willing to undertake PhD studies at the levels of support available and have subsequently filled positions within Canada. Positions have been available for PhD's - these have been filled largely by landed immigrants who have either completed PhD study in Canada or who have come to Canada with a PhD.

The recent increases in both the cost of living and salaries offered by industry to engineering graduates makes it even more urgent that immediate action be taken to increase the support for doctoral students. This is particularly true if post-baccalaureate experience students are to be attracted. Therefore, it is important that more opportunities be available for this particular type of doctoral student in engineering.

Part-Time/Non-Resident Work

CODE would encourage continued experimentation in this regard. It is felt that maintenance of some institutional contact is essential, however. It is felt further that any part-time or non-resident work should normally be by individual arrangement. This would not, of course, preclude special arrangements between a research institution or industry/government laboratories and a particular university or universities.

Inter-University Activities and Facilitating Mechanisms

CODE would support any action designed to increase the effectiveness of the provincial resources in faculties of engineering. The holding of discipline meetings, the sharing of equipment, interchange of credits for graduate courses, collaboration between groups within various institutions and so on are to be encouraged. It is emphasized that co-operation often involves travel and other expenses that are not always readily available in individual schools and that this matter is worthy of further investigation.

It is noted that inter-university activity is proceeding especially at the 'grass-roots' level and this can be aided and abetted by CODE. It is also noted that various university industrial research institutes and similar agencies have facilitated some inter-university cooperation largely through use of individual expertise existing at various institutions.

The Role of the PhD in Entrepreneurship

CODE feels that entrepreneurial activity by PhD's is something which cannot be legislated. However, it feels further that the PhD has, by virtue of his total background, significantly greater potential for success in such activity than has the member of the general populace. It suggests that there are two avenues of encouragement which can lead PhD's in greater numbers into entrepreneurship. The first depends on the educational institution itself, which must, by appropriate orientation and emphasis, develop an interest in or leaning towards innovation, independent practice, or entrepreneurship. The second depends on progressive government support programmes of various kinds, directed to reaching a 'climate' competitive with that found in other industrial economies of comparable size.

Cost-Benefit of the ACAP Studies

CODE has noted that no major measures are proposed that would greatly enhance the quality of the PhD effort in Ontario. Indeed, CODE records its pleasure at the broad and independent affirmation of the consultants as to the strengths and qualities which have developed in Ontario PhD programmes.

The full programme of ACAP studies is as yet incomplete. CODE has yet to be convinced that the extensive funds and efforts devoted to the studies would not have been better spent in direct support of existing PhD programmes in engineering.

ANS/dd
December 27, 1973

APPENDIX A

REPORT ON THE CODE ENGINEERING DOCTORATE EMPLOYMENT SITUATION, OCTOBER 1973

In November 1973, members of the Committee of Deans of Engineering of the Province of Ontario again supplied data on the status of their engineering PhD graduates during the period November 1972 until October 1973. The results are compared in Table 1 with those for 1972.

Again this year, the majority of the graduates were in Chemical, Civil, Electrical and Mechanical Engineering. The total is up substantially to 177 from 124 in 1972.

Unemployment is up from one in 1972 to three in 1973 (approximately 1.7% of the total).

Approximately 17% have left Canada, which is the same as for previous years and is probably due to the return of foreign students to their home countries.

A notable increase in employment in industry has occurred, up to 33% from 21% in 1972. The number employed in Canadian universities is up to 26% from 21% in 1972. This has been accompanied by a decrease in post-doctoral fellowships from 23% to 11%.

The overall conclusion is that there is still no serious unemployment among recent Ontario PhD graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established.

December 13, 1973.

ONTARIO ENGINEERING PH.D EMPLOYMENT SURVEY 1973

The employment status of one hundred and ninety-two graduates with PhDs in engineering from Ontario universities during the period November 72 to October 73 was determined in November 1973.

ENGINEERING DEPARTMENT OR DISCIPLINE	Unemployed		No profess-ional Employment		Employed in Industry		Employed in Government		Employed in Universities		Postdoctoral Fellowships		Have left Canada		Unknown		TOTALS	
	1972	1973	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Aero/Space	-	-	-	-	1	3	-	-	1	3	4	1	-	-	-	-	6	7
Bio-Medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Chemical	-	1	-	-	4	13	1	3	7	5	7	5	3	2	4	2	26	31
Civil	-	1	-	-	5	7	2	5	3	14	6	5	9	7	5	-	30	39
Electrical	-	-	2	-	9	20	3	2	5	11	7	5	4	9	1	-	31	47
Industrial	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	5	0
Materials/Metals	-	1	-	-	1	6	1	-	1	3	2	2	-	3	-	-	5	15
Management	-	-	-	1	-	-	-	-	1	1	-	-	-	1	-	-	1	3
Mechanical	1	-	-	-	4	9	2	5	6	8	1	1	2	7	2	1	18	31
Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Physics/Science	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	0
Systems Design	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	1	0	4
TOTALS	1	3	2	1	26	58	10	16	26	46	28	19	19	31	12	4	124	177

APPENDIX B

Comments on CEMC Report

"Supply and Demand for Engineering Doctorates in Canada" (July 1973)

Submitted by the Committee of Ontario Deans of Engineering

Commendation of this report can be made in a general sense on two main scores. Firstly, the consultants have, on assignment, tackled in a straightforward manner, what is generally acknowledged to be a most difficult task indeed; where qualitatively it is not possible to assert all possible parameters, and quantitatively, it is not possible to obtain reliable data on all accepted parameters.

Secondly, the consultants have in their report introduced with some care statements relating to the qualifications and limitations of the many elements entering into their predictions, and have emphasized that this is only a beginning - ergo, a very preliminary report.

Within this general context, however, there are a number of criticisms to be advanced.

1. Supply

The methodology has been clearly enunciated, and the assumptions stated. Nonetheless, projections have been made on a three-level approach (high, medium and low), establishing bounds which may well be broken as and when certain assumptions become less or more operative. Some indicators are already present as to the dangers of some of the assumptions.

1.1 Admission requirements are not static, and are increasingly adaptable to the changes in the high school. Three other important aspects must be added. There is, firstly, foundation for expecting a major growth in the number of women entering engineering. Secondly, the "market-place" reaction with a rapid response in the 1st year enrolment to a proclaimed shortage in engineers will continue to be operative. Thirdly, there is further indication that advanced admissions (through the stop-outs returning, through technology graduates admissions, etc.) are increasingly important in enrolment projections. None of these has been clearly taken into account in this report. A further aspect could well be added, which is also ignored in the report, but is less easy to define though it will contribute to the instability in prediction of 1st year enrolment. This relates to measuring the full impact of major educational changes on the Canadian scene. The effect of the CEGEP's in Quebec in particular, as well as of the CAAT's in Ontario, is yet to be clearly perceived, let alone settled into a measurable or stable influence.

1.2 The two data bases selected for examination were the number of master's degrees and the number of baccalaureates. The discarding of the master's degrees/doctorate degrees ratio as credible seems to ignore the very recent development of many doctorate programmes as contributing to a rapid change in this ratio. The total postgraduate effort in engineering in Canada is of such an emerging character that rates of change must be evaluated much more carefully. This is equally true for the baccalaureate/doctoral ratio selected as a data base. The evidence for stabilization in this is slight, and even the selection of three ratio levels is likely subject to major error through neglect of variable factors in an easily perturbed system. The changing pattern in the number of Canadian baccalaureates who earn doctorates outside the country is one further feature of a system which as yet has little maturity or stability in it. This aspect of immigration was noted in the resport as one for which no data was available - which ignores one fully-documented part of the system, the Athlone Fellows.

1.3 The utilization of the baccalaureate/doctoral ratio as a data base for predicting future supply has another feature which is inadequately considered and analysed. This relates to the forces which are operative on graduates of Canadian engineering schools vis-a-vis their proceeding to doctoral work. Graduates of the engineering schools of Canadian universities have never come forward in substantial numbers to undertake advanced study and research. The tradition of such a choice, and indeed the number of opportunities for such advanced work. are relatively new on the Canadian scene. The expansion of the graduate schools over the past decade has been effected therefore by the attracting of students with overseas degrees, particularly from Asia. Many of these students from overseas have been or have become landed immigrants, have stayed in Canada and have taken jobs as PhD's. These jobs have been available, they have not been taken up by Canadians who seem to have preferred to enter the work-force earlier, immediately after obtaining the bachelor degree. There are probably many factors which have conditioned the particular choices of Canadian engineering graduates at the bachelor level, but primarily it is probably a combination of (a) the fact that they have been so readily absorbed into the economy at that level, and (b) the fact that the level of financial support available for graduate study has been too low to make them feel that the sacrifice is worth it. For the near future, unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline. At the same time as the graduate schools in engineering become increasingly well established and recognized, and as high technology factors including its encouragement through government policies increasingly become operative, the opposite effect could well occur. The imprecision therefore in assuming a stabilized bachelor/doctoral ratio is greater than assumed in the CEMC study.

1.4 In the consideration of the report, moreover, one should not perhaps overlook the possible impact of events occurring in other jurisdictions. The report suggests that the annual number of bachelor degree graduates will fall from about 4,500 to 3,000 over the next three years, with most of this decrease due to a falling-off in freshmen enrolments in provinces other than Ontario. This could suggest in itself a likelihood of fewer qualified Canadian graduates available for PhD studies at our universities. This must be viewed in conjunction with the situation in the U.S. where undergraduate enrolments in engineering have fallen very sharply over the last few years and this will lead to a very substantial decrease in the number of bachelor engineering degree graduates over the next few years. The combined Canada/U.S. graduating class was about 47,000 in 1971. It will be only about 35,000 in 1975. One might wonder whether, because of excellent opportunities at the bachelor level, a smaller proportion might proceed to PhD work or conversely whether the lack of anxiety about employment prospects at the bachelor level will give more students the confidence to continue with their studies.

1.5 A further major criticism of this part of the report rests not on the methodology, elements of which have been discussed above, but on the basic data used in the calculation steps. Without examination of each and every set of data used, it can nonetheless be indicated that the rather complex combinations of undergraduate enrolment and graduation data from Statistics Canada, from EIC enumerations, from the "Ring of Iron" for Ontario leave some inconsistencies. The number of bachelor's graduations and of doctorates were obtained only to 1970-71, while the number of master's degrees were recorded for 1971-72. In view of the rapid build-up in Canada of doctorate degrees (from 78 in 1965-66 to 216 in 1970-71) it would have seemed to be quite important to establish the 1971-72 figures before final projections were carried out. In view of the prominent place taken by the Ontario system contribution it is indeed surprising that more current data at hand in COU (ACAP) was not utilized. Nonetheless, it is fair to point out that the actual doctorates in Ontario for 1972 and 1973 respectively were 124 and 177, and that the former figure compares to the low level projection for 1971-72 of 126, and the latter to the high level projection of 172 for 1972-73. At least the projection band width used just encompasses the first stages of comparative actual data.

2. Demand

The report includes a comprehensive survey of manpower demand methods, and a careful statement of the method followed for each of the sectors explored, as well as its limitations. This demand aspect of the report is the one which has received the most criticism from the ACAP consultants in the five engineering fields assessed. Our criticisms encompass the major elements of those comments in summary form as well as those voiced by the engineering schools in Ontario.

2.1 Educational Sector

The consultants' use of a model for the estimation of future demand in the educational sector is deceptively attractive. Essentially, their model was based on a staff-student ratio as a base, adjusted for retirement, mortality and migration. They concluded that to 1977-78 (at least) the demand for engineering doctorates would be essentially zero, and then admitted "this will not prove to be an accurate scenario". They then rest their case that in both universities and other educational institutions, the demand will be "minimal". In the dictionary sense of the least attainable or extremely minute in size, it is difficult to read into this other than essentially no demand. Even though rather elegantly derived, we find it hard to accept such a conclusion, particularly when the Ontario system itself projects now a demand for about 20 for 1974. Some of the parameters which would be omitted by the model used include increased demand through major block research grants, through mission-oriented research, and through the development of new programmes and areas. The report does deal at length with the question of "substitutability between inputs", but does not weigh it to the level where it would not be balanced by other factors. This question of substitution will also be referred to below in considering the total demand-supply picture.

2.2 Government and Industry Sectors

In these sectors the consultants chose to establish stock data and forecast demand for 1974, 1975 and 1978 by direct survey. From the many criticisms and indeed specific refutations that can be made, it is clear that this survey has been far too narrowly cast. In the government area this is certainly true regarding the narrowness of definition used. In the industry area it includes not only that limiting factor, but became subject to both incomplete data through using wrong sources, and through important omissions. To some degree the consultants were well aware of these deficiencies, but were obviously more conscious of them for the forecast demand data than for the stock data - where equally gross errors and omissions seem to have occurred. One example of such an error is in the stock of 52 in 1973 attributed to AECL, compared to the 90 actual in 1973 as provided by the Metallurgical engineering consultants in their report to ACAP. Other reports to ACAP specify other examples.

It is hard to escape the conclusion that the inadequacies of the demand survey are far greater than the consultants envisioned, and their errors of omission are much greater than they estimated.

3. General

3.1 Educational Planning and Manpower

What appears to be a basic premise of the report as contained in paragraph 1 on page (1) deserves comment, viz.,

> "Now, a generally accepted view is that the expected labour market for graduates of a particular speciality should influence policy and planning in post-secondary education in that area."

This view may not be as generally accepted as one might be led to believe. The particular philosophy outlined can, taken to extremes, result in a shortsighted and constrained view of a university. It could well be argued that too marked a distinction has been drawn between what is educational and what is vocational. Recently this has been convincingly stated to be one of the major misconceptions in higher education planning*. The danger in assuming that all but preparation of people for specific jobs is wrong or wasteful is not just in the short-sighted effort to establish a one-to-one relationship between education and jobs. Rather it omits the important fact that vocationally oriented education is not wasted if it is not used in the specific vocation toward which it was directed. As Bowen* states, "It is no mark of failure, rather a mark of success, that education - even strictly vocational education - has wide applicability and produces flexible and versatile people". The PhD graduate even if he takes a vocational route initially may well very soon find himself in positions where his PhD can be regarded only as part of his general education or as a contributing factor to his intellectual development or problem-solving ability. It is not difficult to give examples of this "diffusion" of PhD's through a "vocational" period to positions of quite different responsibilities in industry, governments and the universities. The consultants gave careful attention at one stage in their report to this "diffusion" or dispersion, referring properly to the recent University of Toronto study. However, they did not then "factor" it in to either their supply or their demand projections. In our view, significant allowance should be made for it. On the supply side, both into the baccalaureate stream as well as into the doctoral stream in engineering the vocational/educational issue is not clear-cut nor should it be. On the demand side, there must be allowance made both for the substitutability through flexibility even at initial employment levels, and for increasing mobility and transfer into wider areas such as management as experience accrues. The difficulty of quantifying this is well appreciated. The need for including it in some definitive way demands equal appreciation.

3.2 The Supply and Demand Balance

The report in its final results and conclusions comes down strongly on the prediction of an oversupply of engineering PhD's in the decade ahead. They acknowledge a range of factors which will influence both their supply band projection and their demand band projection, including the possible effect of their own report. We acknowledge this danger and can only hope that it can be minimized by vigorous emphasis both on the limitations of the report's projections but also on the countering evidence as it accumulates. We have indicated some of the aspects of both the supply and the demand projections which can invalidate the narrowness of the band widths selected. Perhaps more importantly in the long run is the real failure of any demand projection to be able to take into account any but the very short-term skill requirements of the economy. The evidence is quite clear that our society has an enormous amount of work to be done with a lack of sufficient skilled manpower to do it. We would claim that the adaptability of doctoral graduates in general combined with the adaptability of our economy results in a surprisingly good balance. The Ontario experience, well documented now for four years, indicates essentially no unemployment of engineering doctorates, no unusual hold-up or storage in a post-doctoral form, and changing flows into government and industry as demand from the universities slacken. The acceptance of a current balance, which does exist (with some evidence indeed of unfilled needs in some areas), could well be the starting point for the report's projections. The graphical summary given on page 18 would then present an entirely different picture.

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* H. R. Bowen, "The manpower vs. the free-choice principle", University Affairs, Jan. 1974.

We should rise above our national tendency to be cautious and pessimistic, recognize that even a PhD may be viewed as vocational or educational (hopefully both) according to the graduates perception of the market-place, alternative opportunities, his own desires and so on, and not deliberately cut back on PhD enrolments in engineering, especially on demand data of such doubtful validity as that contained in the CEMC preliminary report. We have so little to gain and so much to lose by taking such an approach. We need to display more optimism and confidence in ourselves and in the ability of highly educated manpower to seek out and create opportunities and to raise the level of some existing positions both in government and industry. It is to be hoped that our students also will display such optimism and take a broader view of the value of their education, and that this view is shared by our federal and provincial governments. We will need this spirit if we are to move into an era in Canadian industry where increasing sophistication and high technology become more and more necessary.

NOTES

Re: 1.1

Entrance to engineering was assumed constant on a demographic base, i.e. 0.5% of male population age 15 to 19; and assumed unchanged entrance requirements.

Re: 1.2 and 1.3

The greatest danger in assuming the validity of a stable B/D ratio for projection purposes resides in the fact that the doctorate figure for the last decade includes a very large but unknown number who did not come through the Canadian baccalaureate stream. The size of that group of doctorates was related largely to immigration policies (now changed and changing), to research grants policies (which have also changed), and possibly to more selective admission policies. Perhaps a meaningful B/D ratio could usefully be established when the D number arises almost entirely from the B stream. Such data have not been collected.